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MAY 1980

Manual of Standards for

SURFACE RUNOFF CONTROL MEASURES

ABAG ASSOCIATION OF BAY AREA GOVERNMENTS

80 003605

San Francisco Bay Area
WATER QUALITY PLANNING PROGRAM

May 14, 1980

TO: Recipients of the Draft Manual of Standards for Surface Runoff Control Measures

FM: Revan A.F. Tranter, Executive Director, Association of Bay Area Governments

We welcome your review of the enclosed document, which complements the Draft Plan Recommendations for amendments to the Bay Area Water Quality Management Plan. Both documents, including the Draft Environmental Impact Report, are the subject of public discussions and hearings during the next two months.

We invite you to participate in the public discussion process, but we especially encourage you to call or write the water quality staff with your recommendations for changes so that we can work with you on possible amendments.

Meetings on the proposed amendments, EIR and manual will be:

May 21	9:30 a.m.	Technical Advisory Committee
June 4	1:30 p.m.	Regional Planning Committee
June 12	1:00 p.m.	Bay Area Citizens Advisory Committee on Water Quality
June 18	9:30 a.m.	Technical Advisory Committee
June 19	7:30 p.m.	ABAG Executive Board (hearing)
July 2	1:30 p.m.	Regional Planning Committee
July 10	1:00 p.m.	Bay Area Citizens Advisory Committee on Water Quality
July 17	7:30 p.m.	ABAG Executive Board (hearing and vote on approval)

All meetings will be held in the Hotel Claremont.

ASSOCIATION OF BAY AREA GOVERNMENTS
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD, SAN FRANCISCO BAY REGION
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MANUAL OF STANDARDS

FOR

SURFACE RUNOFF CONTROL MEASURES

DRAFT

May 1980

Association of Bay Area Governments

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APPENDICES

I. INTRODUCTION

A. OBJECTIVE AND SCOPE OF MANUAL

The objective of this manual is to provide policy guidance, legal guidelines and technical standards with sample specifications for controlling water quality impacts from land use activities in the San Francisco Bay Area. The primary activities covered by the control measures are land development (construction) and public works practices (such as street sweeping). The control measures described in this manual are widely accepted best management practices (BMPs).

Specifically, this manual is designed to serve the following functions:

1. establish policies regarding control of water quality impacts from land development;

2. establish standards and sample specifications to promote uniformly high technical quality in the selection, design, installation and maintenance of erosion and sediment control measures in developing areas;

3. identify cost-effective procedures for street sweeping, catch basin cleaning, and other common public works practices;

It is suggested that cities and counties reference a local adaptation of this manual in appropriate ordinances and regulations of that jurisdiction (such as in the grading and subdivision ordinances).

B. ORGANIZATION OF MANUAL

This manual covers control measures for urban or developing areas (i.e., controls for construction erosion and BMPs for public works practices). Chapter II deals with construction erosion. It begins with a discussion of legal issues, including a Model Grading and Erosion Control Ordinance. Subsequent sections cover erosion and sediment control plans, enforcement procedures and methods for calculating surface runoff and soil loss. Following this general material are the standards and sample specifications for erosion and sediment control measures.

Chapter III deals with public works practices. It begins with a discussion of legal considerations, including a Model Parking Restriction Ordinance for street sweeping. The following sections contain standards for public works practices.

C. USE OF MANUAL

This manual has several intended uses. The model ordinances can be used to revise or amend existing regulations. Appropriate sections of the model grading ordinance can be added to a city or county's current ordinance or the entire model can be adopted as law. The guidelines for erosion and sediment control plans and enforcement practices are intended to be adopted by local planning and public works departments. They could become part of an existing procedures manual or be incorporated into internal guidance memoranda for staff.

The standards and sample specifications for erosion and sediment control are intended to be used as a guide to assist cities and counties in adoption of their own handbook of standards and specifications in support of an erosion control ordinance and program. The locally adopted handbooks would have two recommended uses. One is to provide land developers, design professionals and contractors with detailed technical information to enable them to design and construct effective BMPs. The second is to provide a benchmark for planning and public works department staff to use for assessing the adequacy of control measures proposed in project applications. Plan checkers can compare the standards listed in the manual against those proposed by developers. If the proposed measures are substantially different than what the handbook describes, the permitting agency can ask the developer to justify the adequacy of his measures or make them consistent with the manual.

The standards for public works practices have a different intended use. They are designed to provide information for public works departments on cost-effective practices which can reduce urban pollutants entering water bodies. Public works officials can use this information to revise current practices to improve water quality at little or no additional cost.

D. HOW MANUAL WAS DEVELOPED

The manual was developed from a variety of sources. The model ordinances were based on extensive reviews of existing ordinances in California and other states and published model ordinances. These ordinances were reviewed by ABAG's Water Quality Technical Advisory Committee (TAC) and Citizens Advisory Committee and revised pursuant to the comments of committee members and others.

The sections on erosion and sediment control plans and enforcement were prepared by ABAG based on the following sources:

- Erosion and Sediment Control Handbook, California Department of Conservation

- Public Facilities Manual Volume 3, Fairfax County, Virginia

- Guides for Erosion and Sediment Control, USDA Soil Conservation Services, Davis, California

The standards and sample specifications for erosion and sediment control measures are based on California and national SCS data and "Standards Specifications for Erosion and Sediment Control in Developing Areas" (SCS, Maryland). Some data developed for other areas was adjusted to fit Bay Area conditions. All standards were reviewed by the TAC. ABAG edited standards for appropriateness, clarity and simplicity.

The standards for public works practices were based on mathematical modeling and statistical analyses of local and national data (e.g., data on pollutant accumulation rates on streets and pollutant removal efficiencies of street sweeping and catch basin cleaning practices). Practices which promised water quality benefits were identified. Cost-benefit analyses were performed on these practices. The standards were based on those practices shown to be effective at reducing potential water quality pollutants at little or no additional cost.

II. CONSTRUCTION EROSION AND SEDIMENT CONTROL

A. APPROACH

An effective program for controlling construction erosion and sediment should contain the following major components:

1. an ordinance which establishes the legal basis and public interest in controlling the problem;

2. technical standards and sample specifications which define acceptable control practices;

3. enforcement capability.

The ordinance creates a framework for regulation. It defines the process for reviewing and approving erosion control aspects of construction projects. It should be a flexible document which can be applied to differing conditions. Thus, it should not contain technical details which are likely to change over time or which are better determined on a case-by-case basis.

The standards and sample specifications illustrate proven, effective procedures for construction, operating and maintaining control measures. These technical details define the widely accepted state-of-the-art. They should be contained in a manual or handbook which is referenced in appropriate ordinances (such as the local grading ordinance). Standards and specifications should be continuously revised as control technology improves or as more data on control measure effectiveness become available. Thus, the grading ordinance can keep pace with technology without revision.

Means to improve enforcement capability are provided in this manual in three places. First, the model ordinance sets forth a legal basis for enforcement. A key feature of the ordinance is the requirement for erosion and sediment control plans in project applications. It is much easier to enforce an erosion control plan than it is to enforce non-pollution on a site. For example, if a contractor fails to install a control measure specified in the plan, that is a clear violation of the ordinance. Detailed requirements for the content of erosion and sediment control plans are recommended in Chapter II.D.

The second technique for improving enforcement capability is provided under Enforcement Guidelines Chapter II.E. This chapter presents a checklist for erosion control inspectors to aid them in obtaining developer compliance with the regulations. It also contains a recommended procedure for dealing with violations.

The third means for improving enforcement capability is provided by standards and specifications. By clearly defining acceptable practices in a manual, the enforcement agency (typically a public works department) establishes an enforceable benchmark to determine whether a construction activity conforms with the regulations.

B. PRINCIPLES OF EROSION AND SEDIMENT CONTROL

Erosion is caused by rainfall and runoff. The energy of rain drops displaces soil particles. Rain falling on denuded or paved areas runs off, carrying soil particles down-slope and into stream channels. As the volume and velocity of the runoff increase, soil particles are also removed from the channels. Deposition occurs when the water slows down, such as when channel slope decreases or when barriers or dams are encountered.

The foregoing provides the basic principles for erosion and sediment control:

1) Minimize area and duration of soil exposure;

2) Protect soil with mulch and vegetation;

3) Slow down velocity of runoff with structural control measures (berms, etc.);

4) Reduce volume of runoff through denuded areas by upslope diversions;

5) Prepare drainageways to handle the increased runoff from paved areas;

6) Trap sediment in temporary or permanent basins;

7) Inspect sites adequately and maintain control measures.

C. LOCAL LAWS AND REGULATIONS

This section deals with legal and institutional aspects of:

1. regulation of erosion and sediment from construction activities;

2. destruction of riparian vegetation.

The Model Erosion and Sediment Control Ordinance (Section II.C.1.) addresses the first item above. The Analysis of Watercourse Protection Ordinances (Section II.C.2.) addresses the second item.

The Model Erosion and Sediment Control Ordinance is to be used by local jurisdictions as a guide to evaluating and improving the ability of existing grading ordinances to control surface runoff, erosion and sedimentation. The Model addresses only these particular aspects of grading upon the presumption that the other provisions of the grading ordinance will address questions of slope stability for structures, safety, etc.

Specific sections may be adopted as new code sections or as administrative regulations. Specific sections may be used to revise an existing, parallel section in the grading ordinance. Local jurisdictions should adopt an approach best suited to their needs.

Features of the Model which are enclosed in brackets are particularly susceptible to modification by local jurisdictions. Substantial changes to items not bracketed should be carefully considered. Such changes may undermine the effectiveness of the regulatory scheme.

The Analysis of Watercourse Protection Regulations surveys ordinances and regulations in effect in the ABAG region which directly or indirectly protect and preserve riparian vegetation. The Analysis also sets forth a number of critical considerations which should be applied by local jurisdictions to evaluate their need for and, where needed, effective implementation of such ordinances or regulations.

1. MODEL GRADING AND EROSION CONTROL ORDINANCE

Article I

Title, Purpose and General Provisions

101.00 Title. This ordinance shall be known as the "[City/County] Grading and Erosion Control Ordinance" and may be so cited.

101.01 Purpose. The purpose of this Chapter is to promote and protect the public interest by regulating land disturbances landfill and soil storage in connection with the clearing and grading of land for construction. The intent of this ordinance is to establish administrative procedures, minimum standards of review and implementation and enforcement procedures for the protection and enhancement of the water quality of watercourses, water bodies and wetlands, natural and man-made, by controlling erosion, sedimentation, increases in surface runoff and related environmental damage caused by construction-related activities.

101.02 Definitions. When used in this Chapter, the following words shall have the meanings ascribed to them in this section:

(a) Administrator: the Director of [ ] and duly authorized agents and employees of [ ].

(b) Applicant: any person, corporation, partnership, association of any type, public agency or any other legal entity who submits an application to the Administrator for a permit pursuant to this Chapter.

(c) Best Management Practice (BMP): a technique or series of techniques which, when utilized in a designated manner, is proven to be effective in controlling construction-related runoff, erosion and sedimentation, see subsection 101.02(k).

(d) Erodible slope: a naturally occurring slope greater than 2% and less than 10% for values of K (Soil Erodibility Factor) greater than .25, or greater than 10% and less than 15% for any value of K.

(e) Erosion: the action or process of wearing away of earth or soil by the action of water.

(f) Final Erosion and Sediment Control Plan: a set of measures designed to control surface runoff and erosion and to retain sediment on a particular site after all other planned final structures and permanent improvements have been erected or installed.

(g) Highly erodible slopes: any naturally occurring slope of 15% or greater.

(h) Interim Erosion and Sediment Control Plan: a set of measures designed to control surface runoff and erosion and to retain sediment on a particular site during the period in which pre-construction and construction - related land disturbances, fills and soil storage occur.

(i) Land disturbance/land disturbing activities: any activity moving or removing the soil mantle or top six inches of soil whichever is shallower.

(j) Land fill: any human activity depositing soil or other earth materials.

(k) Manual of Standards (Manual): a compilation of technical application standards and design specifications adopted by the Administrator as being proven methods of controlling construction-related surface runoff, erosion and sedimentation, see 101.02(c).

(l) Permittee: the applicant in whose name a valid permit is duly issued pursuant to this Chapter and his/her/its agents, employees and others acting under his/her/its direction.

(m) Sediment: material deposited by water.

(n) Site: a parcel or parcels of real property owned by one or more than one person which is being or is capable of being developed as a single project.

(o) Wet season: the period from October 15 to April 15.

(p) Soil Erodibility Factor, K:

101.03 Severability and Validity. If any part of this ordinance is found not valid, the remainder of this ordinance shall remain in effect.

101.04 Nuisance Abatement. Neither this Chapter nor any administrative ruling made under it limits:

(a) The power of the [City/County] to declare, prohibit and abate a nuisance; or

(b) The right of any person to maintain, at any time, any appropriate action for relief against any private nuisance, or for relief against any contamination or pollution.

Article II

Permit Application Procedures

201.01 Scope. No person may grade, fill, excavate, store or dispose of soil and earthen materials or perform any other land disturbing or land filling activity without first obtaining a permit as set forth in this Chapter.

201.02 Exemptions. All land disturbing or land filling activities, or soil storage shall be undertaken in a manner designed to minimize surface runoff, erosion and sedimentation. A person performing such activities need not apply for a permit pursuant to this Chapter in the following situations:

(a) Development or construction, on a single lot, of a single family residence when undertaken by the owner, and for which no prior permit pursuant to this Chapter has been issued, provided such activities also meet the requirements of subsection (b) of this section;

(b) Land disturbance or land fill of [1/4 acre], or less; or, where storage or disposal of earth, soil or other earthen materials, the volume of the material is [50 cu. yds.] or less, or [50 tons] or less;

(c) Routine cemetary excavations and fills;

(d) Routine agricultural crop management practices;

(e) Emergencies posing an immediate danger to life or property, or substantial flood or fire hazards;

(f) Except for Subsection (e) of this Section, the exemptions set forth in this Section shall not apply when the activity is undertaken in the following situations;

(1) in highly erodible slope areas,

(2) within 100 feet by horizontal measurement from the top of the bank of a watercourse, the mean high watermark (line of vegetation) of a body of water, or within the wetlands associated with a watercourse or water body, whichever distance is greater, or

(3) during the wet season.

202.00 Application. The application for a permit must include all of the following items:

(a) Application form;

(b) Site map and grading plan;

(c) Interim Erosion and Sediment Control Plan;

(d) Final Erosion and Sediment Control Plan, where required see §301.07;

(e) Soils and Geologic Reconnaissance Report, where required, see §301.05;

(f) Work schedule;

(g) Application fees;

(h) Performance bond or other acceptable security, see §202.07;

(i) Any supplementary material as required by the Administrator.

202.01 Application Form. The following information is required on the application form:

(a) The name, address and telephone number of the applicant;

(b) The names, addresses and telephone numbers of any and all contractors, subcontractors, or persons actually doing the land disturbing activity and their respective tasks;

(c) The name(s), address(es) and telephone number(s) of the person(s) responsible for preparing the site map and grading plan;

(d) The name(s), address(es) and telephone number(s) of the person(s) responsible for preparation of the Interim and/or Final Erosion and Sediment Control Plan;

(e) The name, address and telephone number of the registered [Civil Engineer] responsible for the preparation of the Soils and Geological Reconnaissance Report, where required, see §301.05;

(f) A vicinity map showing the location of the site in relationship to the surrounding area's watercourses, water bodies, and other significant geographic features, and roads and other significant structures;

(g) Date of the application;

(h) Signature of the owner(s) of the site or an authorized representative.

202.02 Site Map and Grading Plan:

(a) The Site Map and Grading Plan shall contain all the following information:

(1) existing and proposed topography of the site taken at not more than a [x-foot] contour interval over the entire site. Ninety percent (90%) of the contours shall be plotted within one contour interval of the true location,

(2) two contour intervals that extend a minimum of 100 feet off-site,

(3) the site's property lines shown in true location with respect to the plan's topographic information,

(4) the location and graphic representation of all existing and proposed natural and man made drainage facilities,

(5) the location and graphic representation of proposed excavations and fills, of on-site storage of soil and other earthen materials, and of on-site and/or off-site disposal. In cases where the location is off-site, a written description of the location will suffice,

(6) the location of all existing vegetation and the location and type of vegetation to be left undisturbed,

(7) the location of surface runoff, erosion and sediment control measures as required under §202.03(d),

(8) the quantity of soil or earthen materials in tons and cubic yards to be excavated, filled, stored or otherwise utilized on-site,

(9) a description of the methods to be used in clearing vegetation, the storage and disposal of the cleared vegetative matter,

(10) the proposed sequence and schedule of excavation, filling and vegetation clearing and other land disturbing and filling activities, and soil or earthen material storage and disposal.

(b) The scale of the site map and grading plan shall be on an engineering scale sufficient to clearly show all details but not less than [X] inch equals [Y] feet.

202.03 Interim Erosion and Sediment Control Plan (Interim Plan). All of the following information shall be provided with respect to conditions existing on the site during land disturbing or filling activities, or soil storage:

(a) Maximum surface runoff from the site shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be more accurate;

(b) Sediment yield shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be more accurate;

(c) The Interim Plan shall contain the following information:

(1) a description and delineation of the measures to be undertaken to retain sediment on the site, including, but not limited to, the design and specification for berms, sediment detention basins, and a schedule for their maintenance and upkeep,

(2) a description and delineation of surface runoff and erosion control measures to be implemented, including, but not limited to, types and method of applying mulches, and, designs for and specifications of diverters, dikes and drains and a schedule for their maintenance and upkeep,

(3) a description and delineation of the vegetative measures to be taken, including, but not limited to, seeding methods, the type, location and extent of pre-existing and undisturbed vegetation, and, in newly vegetated areas, a schedule for their maintenance and upkeep;

(d) The location of all the measures listed by the applicant under subsection (c) above, shall be depicted on the site map and grading plan, see §202.02(a)(7);

(e) An estimate of the cost of implementing and maintaining all interim erosion and sediment control measures must be submitted in a form acceptable to the Administrator.

202.04 Final Erosion and Sediment Control Plan (Final Plan). All of the following information shall be provided with respect to conditions existing on the site after all final structures and improvements except those required under this section, have been completed where none or only a portion of the final structures are covered by a Permit, (see §301.07):

(a) Maximum runoff from the site shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be more accurate;

(b) Sediment yield shall be calculated using the method approved by the Administrator and maintained in the Manual, or any other method proven to the Administrator to be more accurate;

(c) The Final Plan shall also contain the following information:

(1) a description of and specifications for sediment retention devices,

(2) a description of and specifications for surface runoff and erosion control devices,

(3) a description of vegetative measures,

(4) a graphic representation of the location of all items in subsections (1)-(3) above;

(d) An estimate of the costs of implementing all final erosion and sediment control measures must be submitted in a form acceptable to the Administrator.

202.05 Soils and Geological Reconnaissance Report: A Soils Report, when required by the Administrator, see §301.05, shall be based on adequate test borings and shall contain all the following information:

(a) Data regarding the nature, distribution and erodibility of existing soils;

(b) Data regarding the nature, distribution and erodibility of soil to be placed on the site, if any;

(c) Conclusions and recommendations for grading procedures;

(d) Conclusions and recommended designs for interim soil stabilization devices and measures and for permanent soil stabilization after construction is completed.

202.06 Work Schedule. The applicant must submit a master work schedule showing the following information:

(a) The proposed grading schedule;

(b) The proposed conditions of the site on each [July 15, August 15, September 15, October 1 and October 15] during which the permit is in effect;

(c) The proposed schedule for installation of all interim erosion and sediment control measures including, but not limited to, the stage of completion of erosion and sediment control devices and vegetative measures on each of the dates set forth in subsection (b);

(d) The schedule for construction, if any;

(e) The schedule for installation of permanent erosion and sediment control devices where required, see §301.07.

202.07 Security:

(a) The Applicant shall provide security for the performance of the work described and delineated on the approved Grading Plan in an amount to be set by the Administrator but not to exceed 100% of the approved estimate of the cost of the project. The form of security shall be one or a combination of the following to be determined by the Administrator:

(1) A bond or bonds issued by one or more duly authorized corporate sureties. The form of the bond or bonds shall be subject to the approval of the [City Attorney/County Counsel],

(2) A deposit, either with the city or a responsible escrow agent or trust company at the option of the [City/County], of money, negotiable bonds of the kind approved for securing deposits of public monies, or other instrument of credit from one or more financial institutions subject to regulation by the State or Federal government wherein said financial institution pledges funds are on deposit and guaranteed for payment.

(b) The Applicant shall provide security for the performance of the work described and delineated in the Interim Erosion Control Plan in an amount to be determined by the Administrator but not less than 100% of the approved estimated cost of performing said work. The form of the security shall be as set forth in subsections (a)(1) and (2).

(c) The Applicant shall provide security for the performance of the work described and delineated in the Final Erosion and Sediment Control Plan in an amount to be determined by the Administrator but not less than 100% of the approved estimated cost of performing such work. The form of the security shall be as set forth in subsections (a)(1) and (2).

203.01 Fees. The following fees are to be paid pursuant to a schedule of fees adopted and amended from time to time by the [City Council/Board of Supervisors] upon recommendation by the Administrator:

(a) A permit processing fee, to be paid at the time the permit application is submitted;

(b) An inspection fee to be paid at the completion of the work described in the Interim Erosion and Sediment Control Plan;

(c) An inspection fee to be paid at the completion of the work described in the Final Erosion and Sediment Control Plan;

(d) The Administrator may at his option require partial payment of the fees set forth in subsection (b) and (c) of this section before issuing a permit.

204.01 Decision on a Permit. The Administrator shall review all documents submitted pursuant to this Chapter and, if necessary, request additional data, clarification of submitted data or correction of defective submissions within 10 working days after the date of submission. The Administrator shall notify applicant of his decision on the permit within 20 working days of the initial submission or of the corrected submissions, whichever is later.

204.02 Permit Issuance. Approval of an application by the Administrator shall issue within 3 working days.

204.03 Permit Duration. Permits issued under this Chapter shall be valid for the period during which the proposed land disturbing or filling activities, and soil storage takes place or is scheduled to take place, whichever is shorter. Permittee shall commence permitted activities within 60 days of the date the permit is issued or the permit shall lapse and become null and void.

204.04 Permit Denial. The Applicant may request a hearing before the [City Council/Board of Supervisors] within 5 working days of notification of a permit denial. The hearing shall be held within 15 working days.

204.05 Assignment of Permit. A Permit issued pursuant to this Chapter, may be assigned, provided:

(a) The Permittee notifies the Administrator of the proposed assignment;

(b) The proposed assignee:

(1) submits an application form pursuant to §202.01, and

(2) agrees, in writing, to all the conditions and duties imposed by the Permit, and

(3) agrees in writing, to assume responsibility for all work performed prior to the assignment, and

(4) provides security pursuant to §202.07, and

(5) agrees to pay all applicable fees pursuant to §202.08;

(c) The Administrator approves the assignment.

The Administrator shall set forth, in writing, the reasons for his/her approval or disapproval of an assignment.

Article III

Review Standards and Procedures

301.01 Review Policy. The Administrator shall issue a Permit, provided, he/she finds the plans submitted in application for a permit, individually and in the aggregate:

(a) Protects the quality of receiving waters; and

(b) Minimizes surface runoff, erosion and off-site sedimentation:

(1) to the extent feasible, or

(2) in the case where the work site is situated in a §201.02(f) area, to the extent possible.

301.02 Site Map and Grading Plan. Before approving the Site Map and Grading Plan, the Administrator shall find as required by §301.01.

(a) The review process shall include, but is not limited to, examination of the Site Map and Grading Plan for:

(1) adherence to the requirements set forth in §202.02,

(2) certification by a [Civil Engineer, or other qualified persons],

(3) internal coherence.

(b) Where the Site Map and Grading Plan can not be approved as submitted, the Administrator may require the Applicant to adopt one or all of the following measures:

(1) reduce the area of land to be disturbed,

(2) restrict land disturbing or filling activities or soil storage to the dry season, see also §402.01(c),

(3) revise and resubmit site map and grading plan.

(c) The Site Map and Grading Plan, if approved, either as submitted, or as modified under subsection (b) is part of the Permit.

301.03 Interim Erosion and Sediment Control Plan (Interim Plan). Before approving the Interim Plan, the Administrator shall find as required by §301.01.

(a) The Applicant may propose the use of any erosion and sediment control technique in his/her Interim Plan, provided, such techniques are proven to be as or more effective than the equivalent BMP contained in the Manual.

(b) The review process shall include, but is not limited to, examination of proposed techniques, individually, or in the aggregate for its/their:

(1) suitability to and effectiveness under the anticipated conditions at the work site both at the onset of and throughout the wet season,

(2) location(s) on the work site,

(3) size(s), carrying or holding capacity(ies) and design(s) for controlling the predicted surface runoff and sediment yield,

(4) sequencing, both amongst themselves and in concert with land disturbing activities, especially when land disturbing and filling activities and soil storage will commence either at the onset of or during the wet season,

(5) allotted time(s) for full installation and implementation,

(6) proposed maintenance method(s) and schedule(s).

(c) The Administrator shall require the Applicant to change the proposed technique or BMP, or any facet thereof, where (s)he deems necessary.

(d) The Interim Plan, as approved or as modified under §402.02(a), is a part of the permit.

301.04 Final Erosion and Sediment Control Plan (Final Plan). Before approving the Final Plan, the Administrator shall find as required under §301.01.

(a) The Applicant may propose the use of any erosion and sediment control techniques in his/her Final Plan, provided, such techniques are proven to be as or more effective than the equivalent BMP contained in the Manual.

(b) The review process shall include, but is not limited to, examination of each proposed technique, individually, and in the aggregate for its/their:

(1) suitability to and effectiveness under the anticipated conditions on the site throughout the period during which the Final Plan is to be implemented and in effect,

(2) location(s) on the site,

(3) adequacy of the proposed size(s), carrying and holding capacity(ies) and design(s) for controlling the predicted surface runoff and sediment yield,

(4) allotted time(s) for full installation and implementation,

(5) proposed maintenance method(s) and schedule(s).

(c) The Administrator shall require the Applicant to change the proposed technique or BMP, or any facet thereof, where (s)he deems necessary.

(d) The Final Plan as approved or as modified under §402.02(a) is a part of the permit.

301.05 Soils and Geological Reconnaissance Report (Soils Report). A Soils Report meeting the criteria set forth in §202.05 shall be required for all Major Permits. A Soils Report shall also be required for a Minor Permit unless the Administrator determines that all of the following apply:

(a) The soil type for the region in which the work site is situated is recorded in the Manual, an official survey by local state or federal agencies or other widely recognized authority in the field of [ ];

(b) The soil type, as recorded, is sufficiently precise to be utilized in the equations, referenced in §§202.03 (a)-(b) and 202.04 (a)-(b);

(c) The soil on the work site is representative of the region surveyed by the literature of subsection (a);

(d) The site is not in a §201.02 (f) area.

301.06 Work Schedule. The Administator shall review the work schedule for overall coherence. Any modifications to the Site Map and Grading Plan, Interim Plan and Final Plan pursuant to this Chapter, shall be noted on the work schedule.

301.07 Coordination With Other Permits. Where a person applies to the Administrator for a Permit pursuant to this Chapter and either does not apply for the necessary permits to make improvements on the same site or applies for the permits necessary to make only a portion of the prospective improvements on the same site, the Applicant need not submit a Final Plan for the site or those portions of the site wherein Applicant does not plan to make improvements, and this section shall apply.

(a) The Interim Plan shall be adequate to control surface runoff and sedimentation from the unimproved areas of the site for the period of time between termination of the Permit and implementation of a Final Plan, pursuant to subsection (c) of this section, for those areas or portions thereof;

(b) The security for the Interim Plan shall be retained until a Final Plan or Final Plans has been implemented. The security may be released on a pro rata basis where a Final Plan or series of Final Plans is/are implemented for a portion or portions of the site;

(c) No [building permits, permits of occupancy, etc.] shall be issued until the applicant for such a permit has presented to the permitting agency, certification from the Administrator that:

(1) a Final Plan, approved by the Administrator pursuant to this Chapter, has been filed with him/her,

(2) security for the Final Plan has been posted in accordance with §202.07(c),

(3) the applicant presenting such certification, has agreed in writing to implement the Final Plan pursuant to the requirements and enforcement procedures of this Chapter,

(4) The applicant has paid all pertinent fees.

Article IV

Implementation and Enforcement

401.01 Minor Permit.

(a) The Administrator shall issue a Minor Permit only if all the following conditions are met:

(1) the total area of disturbed or filled land is 30,000 square feet, or less,

(2) the total volume of disturbed, filled or stored soil is 1,200 cubic yards, or less,

(3) the slope of the undisturbed land is not highly erodible slope,

(4) the slope of the finished grade is 15% or less,

(5) the land disturbing or filling activities or soil storage does not take place in a §201.02(f) area,

(6) the land disturbing or filling activities, or soil storage does not occur during the wet season.

(b) The Minor Permit is issued subject only to the conditions set forth in §401.03.

(c) The Administrator shall enforce a Minor Permit only through the procedures set forth in §403.01, inspections at the discretion of the administrator or any other means available at law or in equity.

401.02 Major Permits.

(a) All permits other than Minor Permits issued under this Chapter are Major Permits;

(b) The Major Permit is issued subject to the conditions set forth in §§401.03, 402.01-02;

(c) The Administrator shall enforce a Major Permit through the procedures set forth in this Article or any other means available at law or in equity.

401.03 Issuance of Major and Minor Permits. Administrator shall issue a Major or Minor Permit upon approval of a Site Map and Grading Plan, Interim Plan, Final Plan, where required see §301.07, Soil Report, where required see §301.05, and deposit of appropriate security and payment of fees. The Major and Minor Permits shall be issued subject to the following conditions:

(a) The Permittee shall maintain a copy of the Permit, approved plans and reports required under §402.01, on the work site and available for public inspection during all working hours;

(b) The Permittee shall, at all times, be in conformity with approved Site Map and Grading Plan, Interim and Final Plans.

402.01 Implementation of Major Permits--Permittee's Duties. In addition to performing as required under §401.03, Permittee shall:

(a) Notify the Administrator, at least forty-eight (48) hours beforehand, of the beginning of land disturbing or filling activities, or storing soil;

(b) Submit to the Administrator, reports on:

(1) the progress of or delays in land disturbing or filling activities or soil storage,

(2) any other departures from the approved Site Map and Grading Plan which may affect implementation of the Interim or Final Plans as scheduled,

(3) possible delays in obtaining materials, machinery, services or manpower necessary to the implementation of the Interim or Final Plans as scheduled,

(4) the progress of or delays in the implementation of the Interim or Final Plans,

(5) any other departures from implementation of the Interim or Final Plans,

(6) according to the schedule set forth below:

(i) for the period from [April 15] to July 31, monthly;

(ii) for the period from August 1 to September 30, weekly;

(iii) for the period from October 1 to October 15, daily;

(iv) for the period from October 16 to April 14, weekly;

(c) When Permittee proposes to commence land disturbing or filling activities or soil storage during the wet season, Permittee shall demonstrate that land disturbance is relatively minor and that erosion can be easily controlled, or is a necessary and integral part of an Interim Erosion Control plan for previously initiated project phases and where such activities are approved, Permittee shall submit:

(1) a report seventy-two (72) hours prior to and again, at the start of land disturbing or filling, or soil storage activities,

(2) a report seventy-two (72) hours prior to and again, at the start of implementing the Interim Plan,

(3) a report upon completion of the Interim Plan,

(4) any other reports required under subsection (b) of this section.

Each report shall contain, where pertinent, the elements described in subsections (b)(1)-(5) of this section;

(d) Submit to the Administrator, upon termination of the Permit:

(1) a report on and graphic representation of the Final Plan, as implemented, and

(2) a copy of the instructions to be given to the new owners of the improved property by the Permittee or his/her agent regarding the maintenance of the surface runoff, erosion and sediment control measures and devices implemented under the Final Plan, or,

(3) for those areas where no Final Plan is required a report and graphic representation of the Interim Plan, as implemented, and

(4) contracts for the maintenance and upkeep of the surface runoff, erosion and sediment control measures and devices implemented under the Interim Plan, for the period during which the site will remain unimproved;

(e) Have an authorized representative of each contractor or subcontractor actually performing the land disturbing or filling activities, or soil storage actually procuring the materials, machinery, services or manpower for the implementation of Interim or Final Plans sign each report pertinent to him or her, and certify the contents therof as true. The Permittee shall sign all reports submitted to the Administrator and shall attest that each is true and accurate to the best of his or her knowledge.

402.02 Implementation of Major Permits--Administrator's Duties.

(a) The Administrator shall review all reports submitted by Permittee. Where the Administrator finds:

(1) delays in implementing or departures from the approved Site Map and Grading Plan, Interim or Final Plans,

(2) problems with or breakdowns in any technique provided for by the Interim or Final Plan which are attributable to:

(i) the Plans themselves,

(ii) their maintenance methods or schedules,

(iii) any other causes,

which may have a deleterious effect on the quality of receiving waters, or increase surface runoff, erosion or off-site sedimentation, the Administrator shall modify the Site Map and Grading Plan, Interim or Final Plans, and maintenance methods and schedules so as to achieve the same level of water quality and surface runoff, erosion and sediment control as would have been achieved had these problems not arisen. The Administrator shall notify the Permittee in writing of the required changes. Permittee shall comply with the order to modify within [x] working days.

(b) The Administrator shall inspect the work site for compliance with conditions set forth in §401.03, for verification of reports submitted under §402.01, and for the quality of the work being performed under the Interim or Final Plan. Said inspections shall take place:

(1) [within five (5) working days of July 15],

(2) [within five (5) working days of September 1],

(3) [within five (5) working days of September 15],

(4) [weekly from October 1 through 15],

(5) [within three (3) working days of] or during, the first major rainfall of the wet season,

(6) under circumstances described in §402.01(c),

(i) at the onset of implementation of the Interim Plan, and

(ii) at the onset of land disturbing or filling activities, or soil storage, and

(7) after notification to the Permittee of an order to modify under subsection(a) of this section,

(8) at any other time, at the Administrator's discretion.

The inspector shall file a written memorandum on the conditions of the work site and whether Permittee is in compliance with approved plans, in conformity with reports filed by the Permittee and the Interim or Final Plan is effectively controlling surface runoff, erosion and off-site sedimentation.

403.01 Suspension or Revocation of Permit. The Administrator shall resort first to the procedures set forth in this section before resorting to any other enforcement procedure set forth in this Article.

(a) The Administrator shall suspend the Permit, issue a stop work order, and Permittee shall cease all work on the work site upon notification of such suspension when:

(1) Permittee fails to submit reports timely and in accordance with §402.01,

(2) Inspection by the Administrator under §402.02(b)(1)-(8) reveals that the work or the work site:

(i) is not in compliance with the conditions set forth in §401.03, or

(ii) is not in conformity with the Site Map and Grading Plan, Interim or Final Plan as approved or as modified under §402.02(a), or

(iii) is at variance with reports submitted under §402.01(a)-(e), or

(iv) is not in compliance with an order to modify under §402.02(a).

(3) Permittee fails to comply with an order to modify within the time limits imposed by the Administrator, see §402.02(a).

(b) The Administrator shall revoke the Permit and issue a stop work order and Permittee shall cease work upon the occurrence of any of the following conditions:

(1) Permittee fails or refuses to cease work after suspension of the Permit and receipt of a stop work order and notification thereof,

(2) any of the conditions set forth in subsection (a) of this section occurs in a §201.02(f) area.

(c) The Administrator shall reinstate a suspended Permit upon Permittee's correction of the cause of the suspension.

(d) The Administrator shall not reinstate a revoked Permit.

403.02 Fines and Penalties: It shall be a misdemeanor for any person to perform work in violation of a stop work order issued pursuant to §403.01 (a)-(b). The [City/County] may impose a fine of $500 or a prison term of thirty (30) days for each day that:

(a) Permittee continues working in violation of a stop work order;

(b) Permittee is not in compliance with the Interim Plan or Final Plan at the onset of the wet season.

403.03 Action Against the Security. The Administrator may request the [City Attorney/District Attorney] to commence an action against the pertinent security if:

(a) The Permittee ceases land disturbing activities and abandons the work site prior to completion of the Site Map and Grading Plan;

(b) The Permittee fails to conform to the Interim Plan, as approved, or as modified under §402.02(a);

(c) The Permittee fails to comply with the Final Plan or an Interim Plan, as approved or modified under §402.02(a); or the techniques utilized under either Plan fail within one (1) year of installation, or until a Final Plan is implemented for the site or portions of the site, whichever is later;

(d) The monies obtained from a successful action against the Security shall be used to finance remedial work undertaken by the [City/County] or a private contractor under contract to the [City/County], and to reimburse the [City/County] for the cost of litigation;

(e) Securities held against the successful completion of the Site Map and Grading Plan and the Interim Plan, except for Interim Plans described in §301.07 shall be released to the Permittee at the termination of the Permit, provided no action against such security is filed prior to that date;

(f) Securities held against the successful completion of the Final Plan and an Interim Plan described in §301.07 shall be released to the Permittee either one (1) year after termination of the Permit or when a Final Plan is submitted for the unimproved site, provided no action against such security has been filed prior to that date.

403.04 Cumulative Enforcement Procedures. The procedures for enforcement of a Permit, as set forth in this Article, are cumulative and not exclusive.

2. ANALYSIS OF WATERCOURSE PROTECTION REGULATIONS

Definition

Watercourse protection regulation may be self-contained ordinances or a set of amendments to existing ordinances or regulations which are designed to protect and preserve riparian vegetation.

Purpose

To regulate an activity or set of activities in and near a watercourse which may directly or indirectly harm or destroy riparian vegetation.

Benefits

Riparian vegetation stabilizes the banks of watercourses, slows surface runoff and traps surface runoff pollutants and thereby reduces erosion and sedimentation and consequent degradations in water quality.

Design Considerations

The watercourse protection regulations should:

- o establish the authority of the administrative agency over the watercourse and areas nearby;
- o establish the authority of the administrative agency over all or specified activities within the regulated area;
- o establish an efficient and low cost system for implementation and enforcement of the regulations.

Analysis

A survey and evaluation of watercourse protection regulations in this region reveals a diversity of approaches to watercourse protection regulation.

One feature common to all such regulations is the incorporation of watercourse protection criteria with other public policy goals. Thus, administrative agencies whose first concern is not water quality is given power and responsibility to apply watercourse protection criteria. The agency assigned this task ought to be the one which can most efficiently and effectively apply the criteria and administer the regulations.

Table II.C.2.1. lists some of the agencies applying watercourse protection regulations in this region. The local jurisdiction should examine local conditions and administrative agencies in the following manner:

- o identify those agencies, local, state and federal which have jurisdiction over the local watercourses;

TABLE II.C.2.1

WATERCOURSE PROTECTION REGULATIONS

Agency	Enabling Legislation	Primary Goal(s)	Water Quality Criteria	Areal Jurisdiction	Activity(ies) Jurisdiction
Army Corps of Engineers	P.L.92-500 § 404	Water Quality	Preservation of water as habitat for fish	Below the headwaters of any watercourse	Any activity involving discharge of dredge or fill material into a watercourse with a flow >5 cfs
California Dept. of Fish and Game	CA Fish & Game C. §§ 1601-1603	Water Quality	Preservation of water as habitat for fish	Any watercourse supporting or capable of supporting a fish population and its banks	Any activity which may affect habitability of the waters
Santa Clara Valley Water District	Ordinance No. 74-1	Floodplain Management, Water Supply	Pollution by any material of water supplies	The watercourse and 50 feet on either side	Any construction or deposit of any materials in the area, planting or trespass
Napa County (FCD)	Ordinance No. 627	Floodplain Management	Preservation of riparian vegetation	100 year floodplain (FIRM) of designated watercourses	Construction, excavation, fill, clearing, planting, hydrodynamic modifications.
Solano County	Ordinance No. 1090	Land use zoning, Water Quality	Preserve riparian habitat, control erosion and sedimentation	Designated watercourses plus 150 feet on either side	Excavation, fill, construction, maintenance, land disturbance and devegetation
Napa County	Ordinance No. 432	Timber harvesting practices in re. conservation, pollution, etc.	Control soil erosion, sedimentation & other pollution of waters.	The harvesting area and watercourses along which timber harvesting occurs.	Timber harvesting and activities, e.g., attendant stream crossings, tractor roads.
ABAG, Model Erosion & Sediment Control Ordinance		Water quality.	Control surface runoff; erosion and sedimentation.	The construction site with special emphasis on area within 100 ft. of a watercourse.	Construction related land disturbances, land fill and soil storage.

- o identify the activities which these agencies engage in and/or regulate within and near a watercourse;

- o identify the various policy goals these agencies are pursuing;

- o identify the implementation and enforcement procedures used by these agencies to achieve their goals.

From this data, a local jurisdiction should determine whether:

- o the land area and activities covered by the agency is comprehensive from a watercourse protection standpoint;

- o the agency's own activities, if any, are compatible with watercourse protection criteria;

- o the agency's implementation and enforcement procedures are adequate to effectively and efficiently apply watercourse protection regulations.

In the local jurisdiction's attempt to make each of the determinations set forth above, it should be aware of the following considerations:

- o The exact size of the area which ought to be regulated in order to preserve riparian vegetation is not precisely determinable from current scientific data and principles.

- o The type and intensity of activities which ought to be allowed in the regulated area is also not precisely determinable from current scientific data and principles.

- o Where an agency's own activities may be incompatible with water quality goals, such as Flood Control Districts' channelization of streams and their other hydrodynamic modifications, then an important policy judgment must be made by the local jurisdiction. Should the basic conflict be resolved by the agency in question or should it be resolved through the interaction between that agency and another agency chosen to administer the regulations? The first alternative appears intuitively to be less costly. The second may provide a greater degree of protection for the watercourse environment. No data has been compiled by ABAG on which alternative is more cost efficient. Aside from cost considerations, the possible high political visibility which would result from interagency disputes is probably not desireable, without more substantial technical data to support regulation.

- o Implementation and enforcement of watercourse protection regulations may present few adminstrative problems to the designated agency for those areas and activities currently under its purview. Some activities which may harm or destroy riparian vegetation are, in general, unregulated, e.g.,

private clearing of riparian vegetation for landscaping, weed control, etc., agricultural clearing and use of various chemicals harmful to riparian vegetation. Attempts to expand an agency's jurisdiction and powers to include such activities must be carefully coordinated with the addition of or changes to appropriate implementation and enforcement procedures.

Recommendations

ABAG recommends that each jurisdiction perform the preceding analysis and implement watercourse protection regulations where needed. ABAG cannot recommend the designation of specific agencies to administer such regulations, or consequently, the format for implementation and enforcement of such regulations.

D. EROSION AND SEDIMENT CONTROL PLAN

Erosion and sediment control plans are a vital element of a local government's regulatory program. The requirements for an erosion and sediment control plan should be included in a grading ordinance or specified in administrative procedures, such as in a BMP manual (See Chapter II.9.).

The Erosion and Sediment Control Plan

1. Definition

   An erosion and sediment control plan is a document which specifies how erosion and sediment will controlled on a construction site in compliance with laws, ordinances and accepted standards and specifications.

   (The grading ordinance should specify the minimum project size which requires an erosion and sediment control plan. All but the smallest projects [for example, projects less than one-quarter acre not in a sensitive area] should require such a plan. For the small, exempt project, a brief statement of the erosion and sediment control measures to be taken will, in most cases, be sufficient.)

2. Plan Preparer

   The plan shall be prepared by a person or firm qualified by training and experience to have expert knowledge of erosion and sediment control methods. The plan shall be signed by its preparer.

3. Content

   The plan shall consist of three parts:

   (a) A narrative, containing:

      o brief description of overall project

      o date project will begin and the expected date of final

      o phasing of land-disturbing activities, including removal and stockpiling of topsoil

      o brief description of erosion and sediment control measures to be implemented, including both temporary and permanent measures

      (Note: Measures must meet or exceed all requirements in grading ordinance and applicable standards and specifications. If grading is scheduled to be completed prior to start of rainy season, the plan should specify

contingency actions to winterize site in the event that construction falls behind schedule.)

- o maintenance program, including frequency of inspection, reseeding of vegetated areas, repair or reconstruction of damaged structural measures, method and frequency of cleanout, disposal of waste materials, and disposition of control measures after they have served their purpose (See Figure II.D.1)

(Note: This narrative is intended to briefly summarize for the plan checker the aspects of a project which are important for erosion control. It is not intended to duplicate the requirements of project applications and EIRs. Applicable portions of those documents should be referenced in the narrative.)

(b) A map showing:

- o exissting topography and site conditions
- o the location of the project relative to highways, municipalities, major streams, or other identifiable landmarks
- o acreage of the project
- o contours at an interval and scale sufficient for distinguishing runoff patterns prior to and after disturbance
- o limits of clearing and grading
- o critical environmental areas located within or near the project areas, such as stream, lakes, ponds, wetland areas
- o nature and extent of existing vegetation
- o surface area of each soil type and relative erodibility
- o location and types of both temporary and permanent control measures
- o dimensional details of facilities (See Figure II.D.2)

(c) Construction drawings or sketches and supporting data, including:

- o key dimensions and other important details
- o engineering and design assumptions and calculations (for structural measures)

o brief analysis of problems posed by storm runoff on downstream areas

FIGURE II.D.1. SAMPLE NARRATIVE

EROSION AND SEDIMENT CONTROL PLAN

Description

The project is a 4,000 square-foot school building with exercise fields on a 6-acre site.

Dates of Construction

Project scheduled to start on June 15, 1980 to be completely stabilized by December 1977.

Soil Data

The entire site is Glenelg silt loam, eroded rolling phase; this soil ranges from moderately to severely erodible.

Tree Protection

Trees along the perimeter are to be protected from equipment damage by signs and fences at the drip-line.

Erosion Control Program

Seed and straw mulch are to be applied to each graded area not later than September 15, 1980, except for building areas plus a thirty-foot border and streets and parking areas. The straw will be anchored by punching with a roller.

Sediment Control Program

Control will be exercised through installation of one earth sediment dam of 0.5 acre-foot capacity and a minor sediment basin of 0.15 acre-foot capacity, with 1,500 feet of earth diversions directing storm runoff to the basins.

Sequence of Land Disturbing Activities

In June and July 1980 the school site and surrounding area will be stripped and the topsoil stockpiled at the southeast corner of the site. This area will then be brought to grade without disturbance to other areas. Construction of sediment basins and diversion dikes will commence thereafter and be completed before October 15, 1980. All areas brought to grade, except the building site, will be seeded with temporary vegetation and mulched by September 15, 1980.

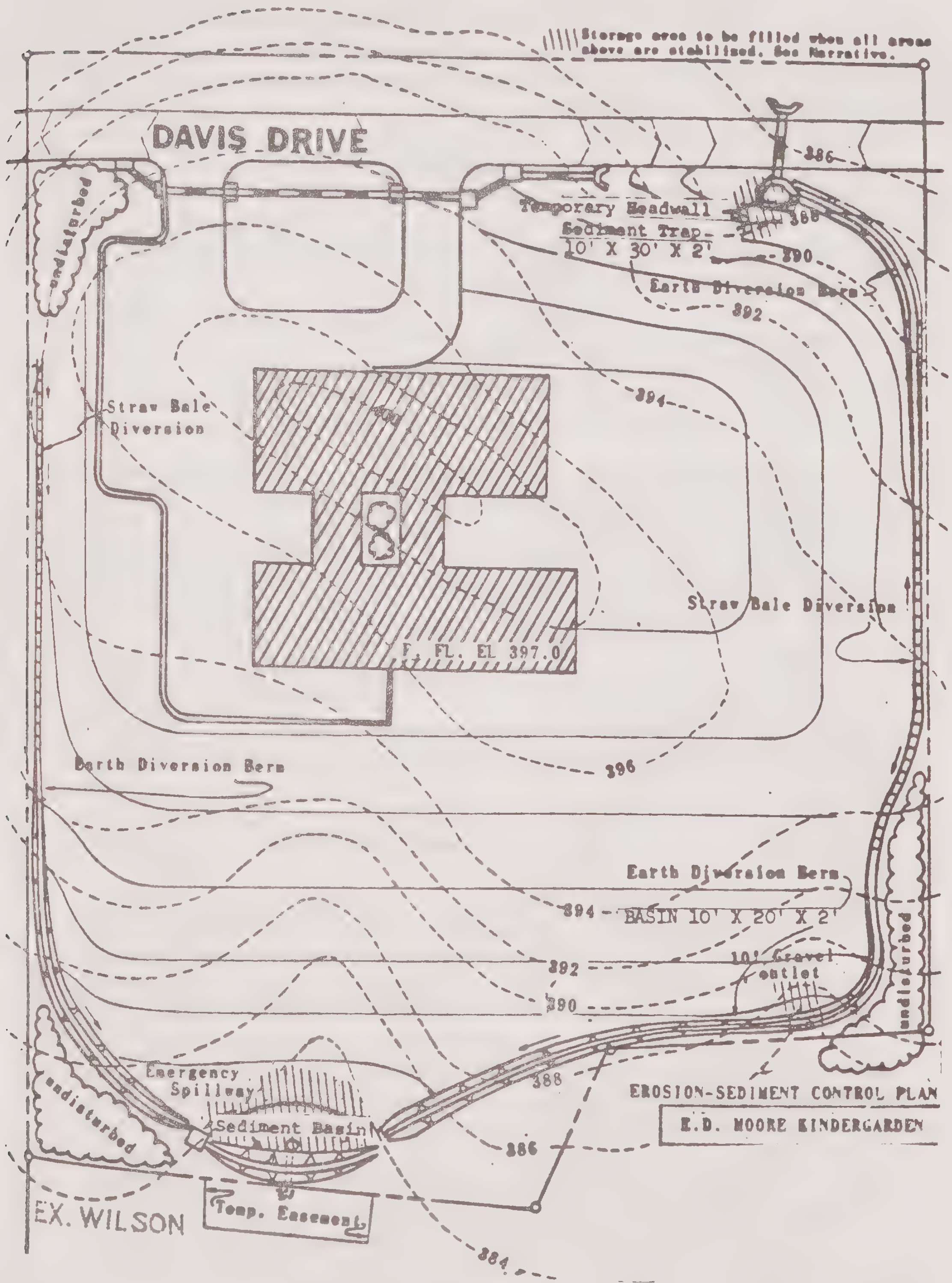
Maintenance Program

All measures are to be inspected daily by the site superintendent or his representative. Any damaged structural measures will be repaired by the close of the day. Sediment basins are to be cleaned out at 50% trap

efficiency level and the material disposed of by spreading on the site. Diversions may be removed after areas above them have been stabilized with grass or mulch. The sediment basin at the south end wil not be removed until all other mechanical measures have been removed and the areas stabilized. No controls are to be removed without approval of the site inspector.

(Adapted from Public Facilities Manual, Volume 3, Fairfax County, Virginia, 1978)

FIGURE II.D.2. EXAMPLE MAP FROM EROSION AND SEDIMENT CONTROL PLAN



(Adapted from Public Facilities Manual, Volume 3, Fairfax County, VA 1978)

E. ENFORCEMENT GUIDELINES

A good grading ordinance will require an erosion control plan prior to issuance of a grading permit. In the erosion control plan, each developer must provide detailed specifications showing how erosion will be controlled on a project site.

The combination of ordinance, manual and erosion control plan form the written requirements. One job of the construction inspectors is to ensure that erosion and sediment are controlled on the actual site. It is recommended that each city and county adopt enforcement guidelines as official public works department procedures.

The following enforcement guidelines for construction site inspector are based on current practices in Fairfax County, Virginia.

1. Initial Site Review (Preconstruction Meeting)

   Prior to the start of work, meet the Field Superintendent at the site to review plan requirements. Go over the planned construction sequence and the corresponding schedule for installation of erosion and sediment control measures to see that the Superintendent has thought through all phases of the job. Go over all the notes. Look at the problem areas with him such as steep slopes above ponds and streams. On sites where soil may be particularly erodible, it is recommended that an SCS or RCD advisor or soils engineer accompany the inspector on the first site visit. Consult the SCS field offices in Concord, Dixon, Gilroy, Half-Moon Bay, Livermore, Napa, Petaluma, San Jose or Santa Rosa for availability of SCS personnel.

   Review the planned control measures with attention to these items:

   (a) Siting Adjustments - Locations of control measures in the plans may have to be adjusted to fit actual site conditions. If the controls do not make good sense, it is the inspector's responsibility to see that necessary adjustments are made. In addition, these changes should be brought to the attention of the department supervisor.

   (b) Alterations to Timing and Measures - Judgment must be exercised in allowing or requiring changes as construction progresses. If the actual construction schedule varies from that specified in the grading plan, changes in control measures may be necessary.

2. Start of Work

   (a) Erosion and sediment controls (dikes, dams, etc.) should be placed prior to or as the first step in grading, if grading begins in the rainy season.

(b) Dikes, stockpiles and dams should be seeded for temporary vegetative cover and mulched before September 15. Urge the contractor to use excavated top soil for berm or dike material. This provides an out-of-the-way stock pile which is easily vegetated.

(c) Read the weather reports. See that the Superintendent is ready for rain when it starts. Contractors are seldom prepared for rain, particularly the first rain.

(d) Visualize runoff patterns during a heavy rain. Be sure that streams and storm drains below the site will not be damaged by runoff from such a storm.

(e) See that unpaved site access roads which drain to existing roads have interceptors to prevent soil from being deposited onto the existinng roads.

(f) Insure that the Superintendent has an information program to keep equipment operators aware of the locations and requirements for control measures so that they do not unintentionally destroy them. Likewise, there should be a program to keep vehicles, equipment and materials out of areas that do not have to be disturbed.

3. Construction Continuation

(a) Inspector - Superintendent Relationship - Maintain communications with the Superintendent; the job can't run well without mutual cooperation. Ask about progress reports. Ask him to prepare for removing controls as work approaches completion (if they need to be removed). The inspectors should deal with the Superintendent, not his subcontractors. If the Superintendent is habitually not available, contact the developer or owner.

(b) Maintenance- Check maintenance of existing erosion controls; all sediment basins and traps need cleanout, and diversions need periodic reshaping and dressing. All dams should have a specified cleanout level which the inspector should be able to recognize. During the rainy season, dams and berms cut through for utilities should be restored as soon as possible. Make a special check whenever rain is forecasted and see that the Superintendent has designated someone to check control measures daily and to make repairs.

(c) Storm Drainage System - Watch development of the storm drainage system. As soon as any pipe is in the ground, manholes, inlet structures and walls should be installed so that proper controls can be built and the area will not have to be torn up again. As the system is built, attention must be turned to preventing sediment from

entering the system. The volumes and velocities of water coming out from drainage structures are generally too great to easily control there. The control should be shifted to the inlets. As the site progresses, the inlet protection should change from excavated silt traps to rock filters at the inlets, or other equivalent measures. Do not use straw bales at inlets or outlets at any time. Do not ever allow inlets to be blocked.

(d) Drainage - Construction drainage: The site should drain so that it can be worked, but it should drain slowly so that a minimum of soil will be washed off-site. Ensure drainage of all traps--every basin, whether that behind a large dam or the one at a storm sewer inlet must drain. Standing water is a hazard, a nuisance to construction and a problem for compaction. If water remains ponded longer than 24 hours, see that drains and filters are cleaned out and reshaped.

Particular care is required if the construction is close to occupied buildings. Inlet protection should not prevent the inlet from functioning and possibly causing flooding of adjacent properties. Major sediment basins attract children and fencing is almost mandatory if there are occupied houses within 200 yards. Even with fencing, early drainage of each pond after a storm is necessary to reduce the possibilities of accidents.

(e) Fall seeding - Remind the contractor of the requirements for seeding and mulching. Tell him to get advice on this from the District Conservationist. Seeding equipment should be ready to go right after fine grading and seedbed preparations.

All seed and mulch should be in place by September 15. Check contractors' preparations to meet this deadline. Make the contractor keep all controls operative until all the area above each control is fully stabilized. Seedbeds should be seeded the same day they are prepared. This practice will prevent the need for regrading and replacing topsoil on slopes.

(f) Stockpiles - Stockpiles of soil are commonly created which are not shown on the plans. During the rainy season, all stockpiles should be seeded as soon as they are created, since they normally remain a long time. A diversion should be established above each stockpile. Do not let contractor cover up controls or bury trees with these spoils.

(g) Compaction - Poor compaction of berms, dams and fill slopes leaves highly erodible soil masses. Get the contractor to walk-in all fills in low lifts with tracked

equipment or compactors. Cleat marks should be on the contour.

4. Construction Completion

   (a) Restoration - Ensure that all sediment dams, berms and other controls are removed, regraded, seeded and mulched before demobilization. If any silt dam is to be left in place permanently (as shown on the plan), see that it is cleaned out and the embankment and bottom covered with a good stand of grass. Many diversions may be left in place but authorization should be obtained from the permit-issuing agency.

   (b) Cleanup - Insist that any areas disturbed during final cleanup be seeded and mulched at once.

5. Violations

   The following procedure should be used:

   (a) First inform Superintendent and developer verbally that they are not in compliance.

   (b) If action is not taken within the specified time (a practical time for making necessary corrections), issue a written violation notice to the developer.

   (c) The violation notice must contain the following:

      o citation of the pertinent ordinance

      o description of what the violation is and what must be done to correct it

      o deadline for correction

      o signature of inspector

   (d) Submit one copy to department supervisor and one copy to the developer. (To eliminate criticism from developers, it is advisable for the inspector or his supervisor to give notice of the violation to the Superintendent on-site the same day the violation is written. This procedure gives the developer the benefit of the full amount of time granted for correction.)

   (e) Follow-up violation notice with a site inspection on the last day allowed for correction or one or two days thereafter. Fill out a Violation Status Report which either:

      (1) releases the violation if the work has been done, or

(2) indicates the work has not been done and makes a recommendation as to further action required.

(f) Submit copies of Violation Status Report to both department supervisor and developer.

Department supervisor then takes appropriate action pursuant to the grading ordinance.

F. CALCULATING SURFACE RUNOFF AND SOIL LOSS

Soil Loss

Five methods of predicting the degree of erosion are given here. These equations are alternative methodologies; the selection of which to use depends upon the accuracy desired, the time available, the precision with which the inputs are known, and the expertise of the available personnel. These techniques predict only the amount of soil moved from its original position. They do not estimate net soil erosion nor can the results indicate the sediment yield of a river basin. The first three methods calculate sheet erosion occurring more or less uniformly over an area of land surface. To this amount of erosion must be added the erosion activity occurring on any roadway cut and fill areas present. Techniques for computing this type of erosion are presented as the last two methods in this section. Gully erosion, which may also occur, is dealt with elsewhere (U.S. Soil Conservation Service, 1966; 1975).

The five methodologies discussed here do not represent an exhaustive listing of techniques in current use. Rather they serve to illustrate the types of factors generally considered influential to the degree of erosion occurring. The reader is referred to the source documents and other bibliographical entries for more complete discussions before attempting to calculate soil loss. The five methods given here are:

1. Pacific Southwest Interagency Committee Method (Amimoto, 1978).

2. Sediment Predictive Yield - Flaxman Method (Amimoto, 1978).

3. Universal Soil Loss Equation (U.S. Soil Conservation Service, 1975).

4. Road Density vs. Sediment Production Method (Amimoto, 1978).

5. Surface Area of Cut and Fill Method (Amimoto, 1978).

Pacific Southwest Interagency Committee Method

This method is qualitative and should not be used when precise numerical predictions are required. The sediment yield is estimated in terms of acre-feet per square mile per year. Table II.F.1, with the accompanying example, presents this method.

TABLE II.F.1. PACIFIC SOUTHWEST INTERAGENCY COMMITTEE METHOD FOR ESTIMATING SOIL LOSS

Sediment Yield Levels	A SURFACE GEOLOGY	B SOILS	C CLIMATE	D RUNOFF	E TOPOGRAPHY	F GROUND COVER	G LAND USE	H UPLAND EROSION	I CHANNEL EROSION & SEDIMENT TRANSPORT
High	(10)* a. Marine shales and related mudstones and siltstones.	(10) a. Fine textured; easily dispersed; saline-alkaline; high shrink-swell characteristics. b. Single grain silts and fine sands	(10) a. Storms of several days' duration with short periods of intense rainfall. b. Frequent intense convective storms c. Freeze-thaw occurrence	(10) a. High peak flows per unit area b. Large volume of flow per unit area	(20) a. Steep upland slopes (in excess of 30%) High relief; little or no floodplain development	(10) Ground cover does not exceed 20% a. Vegetation sparse; little or no litter b. No rock in surface soil	(10) a. More than 50% cultivated b. Almost all of area intensively grazed c. All of area recently burned	(25) a. More than 50% of the area characterized by rill and gully or landslide erosion	[illegible] a. Eroding banks continuously or at frequent intervals with large depths and long flow duration b. Active headcuts and degradation in tributary channels
**									
Moderate	(5) a. Rocks of medium hardness b. Moderately weathered c. Moderately fractured	(5) a. Medium textured soil b. Occasional rock fragments c. Caliche layers	(5) a. Storms of moderate duration and intensity b. Infrequent convective storms	(5) a. Moderate peak flows b. Moderate volume of flow per unit area	(10) a. Moderate upland slopes (less than 20%) b. Moderate fan or floodplain development	(0) Cover not exceeding 40% a. Noticeable litter b. If trees present understory not well developed	(0) a. Less than 25% cultivated b. 50% or less recently logged c. Less than 50% intensively grazed d. Ordinary road and other construction	(10) a. About 25% of the area characterized by rill and gully or landslide erosion b. Wind erosion with deposition in stream channels	(10) a. Moderate flow depths, medium flow duration with occasionally eroding banks or bed
**									
Low	(0) a. Massive, hard formations	(0) a. High percentage of rock fragments b. Aggregated clays c. High in organic matter	(0) a. Humid climate with rainfall of low intensity b. Precipitation in form of snow c. Arid climate, low intensity storms d. Arid climate; rare [illegible]	(0) a. Low peak flows per unit area b. Low volume of runoff per unit area c. Rare runoff events	(0) a. Gentle upland slopes (less than 5%) b. Extensive alluvial plains	(-10) a. Area completely protected by vegetation, rock fragments, litter Little opportunity for rainfall to reach erodible material	(-10) a. No cultivation b. No recent logging c. Low intensity grazing	(0) a. No apparent signs of erosion	(0) a. Wide shallow channels with flat gradients, short flow duration b. Channels in massive rock, large boulders or well vegetated c. Artificially controlled channels

* THE NUMBERS IN SPECIFIC BOXES INDICATE VALUES TO BE ASSIGNED APPROPRIATE CHARACTERISTICS. THE SMALL LETTERS a, b, c, REFER TO INDEPENDENT CHARACTERISTICS TO WHICH FULL VALUE MAY BE ASSIGNED.

** IF EXPERIENCE SO INDICATES, INTERPOLATION BETWEEN THE 3 SEDIMENT YIELD LEVELS MAY BE MADE.

In most instances high values for the A through G factors should correspond to high values for the H and/or I factors.

Rating Table

Rating	Sediment Yield AF/sq.mi.
>100	3.0
75 - 100	1.0 - 3.0
50 - 75	0.5 - 1.0
25 - 50	0.2 - 0.5
0 - 25	<0.2

AN EXAMPLE OF THE USE OF THE RATING CHART IS AS FOLLOWS:

A watershed of 15 square miles in western Colorado has the following characteristics and sediment yield levels:

	Factors	Sediment Yield Level	Rating
A	Surface geology	Marine shales	10
B	Soils	Easily dispersed, high shrink-swell characteristics	10
C	Climate	Infrequent convective storms, freeze-thaw occurrence	7
D	Runoff	High peak flows; low volumes	5
E	Topography	Moderate slopes	10
F	Ground cover	Sparse, little or no litter	10
G	Land use	Intensively grazed	10
H	Upland erosion	More than 50% rill and gully erosion	25
I	Channel erosion	Occasionally eroding banks and bed but short flow duration	5
		Total	92

This total rating of 92 would indicate that the sediment yield is between 1.0 and 3.0 AF/sq.mi. based on Rating Table.

Sediment Predictive Yield - Flaxman Method

This method computes sediment yield on an average annual rate in acre-ft. per square mile per year. The required inputs are:

Precipitation/Temperature Ratio (X1):

Average annual precipitation (inches) divided by average annual temperature (degrees F). Use X1 = 0 where vegetation has been stripped for development.

Slope (X2):

Use the weighted average slope such as the contour interval divided by the average width between contours.

Soil Particle Size (X3):

Percent of soil particles coarser than 1 millimeter in the uppermost 2 inches of soil.

Aggregation Index (X4):

Percent of soil 2 microns or finer in size in uppermost 2 inches of soil. Use (+) if pH is alkaline and (-) if pH is acid or neutral (7.0).

The result of the computation is:

Sediment Yield (Y):

The sediment yield is in units of acre feet per square mile per year.

The equation used to compute sediment yield by this method is:

$$\begin{aligned}\log (Y + 100) = {} & 6.63792 - 2.13712 \log (X1 + 100) \\ & + 0.06284 \log (X2 + 100) \\ & - 0.01616 \log (X3 + 100) \\ & + 0.07073 \log (X4 + 100)\end{aligned}$$

Sheet Erosion Computation Universal Soil Loss Equation

This method of computing sediment yield is in wide use and is simple to calculate once appropriate values of the input variables are obtained. The required inputs are:

Rainfall Factor (R):

The intensity of rainfall, the mechanism responsible for the detachment of soil particles.

Soil Erodibility Factor (K):

A measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff.

Slope Length-Gradient Factor (SL):

The combined effect of the geometric features of the site relative to the standard geometry of a basic 9% slope, 72.6 feet long.

Cropping-Management Factor (C):

The effect of protection against erosion provided by vegetation.

Erosion-Control Practice Factor (P):

The ratio of soil loss with the supporting practice to the soil loss with up-and-down hill culture.

The result of the computation is:

Sediment Yield (A):

The sediment yield is in units of tons per acre per year.

$A = RKSLCP$

<u>Road Density vs. Sediment Production Method</u>

This method can be used in the San Francisco Bay Area. It can only give a qualitative estimate of the erosion yield due to roadways. This method should be used only in areas of steep topography, moderately erodible soil and moderate rainfall. To estimate sediment production in acre-feet per square mile per year by this method, use the graph on Figure III.F.1.

<u>Surface Area of Cut and Fill Method</u>

This method computes sediment yield due to roadways by multiplying the graphically determined area of cut and fill, by th assumed average depth of erosion on the cut and fill area. Figures II.F.2 through II.F.4 show graphs which determine the cut and fill area for 20, 60 or 100 foot wide roadways. The surface area of cut and fill is given in acres per mile. Upon multiplication by the assumed erosion depth in feet, the acre feet per road mile per year of sediment yield results.

FIGURE II.F.1

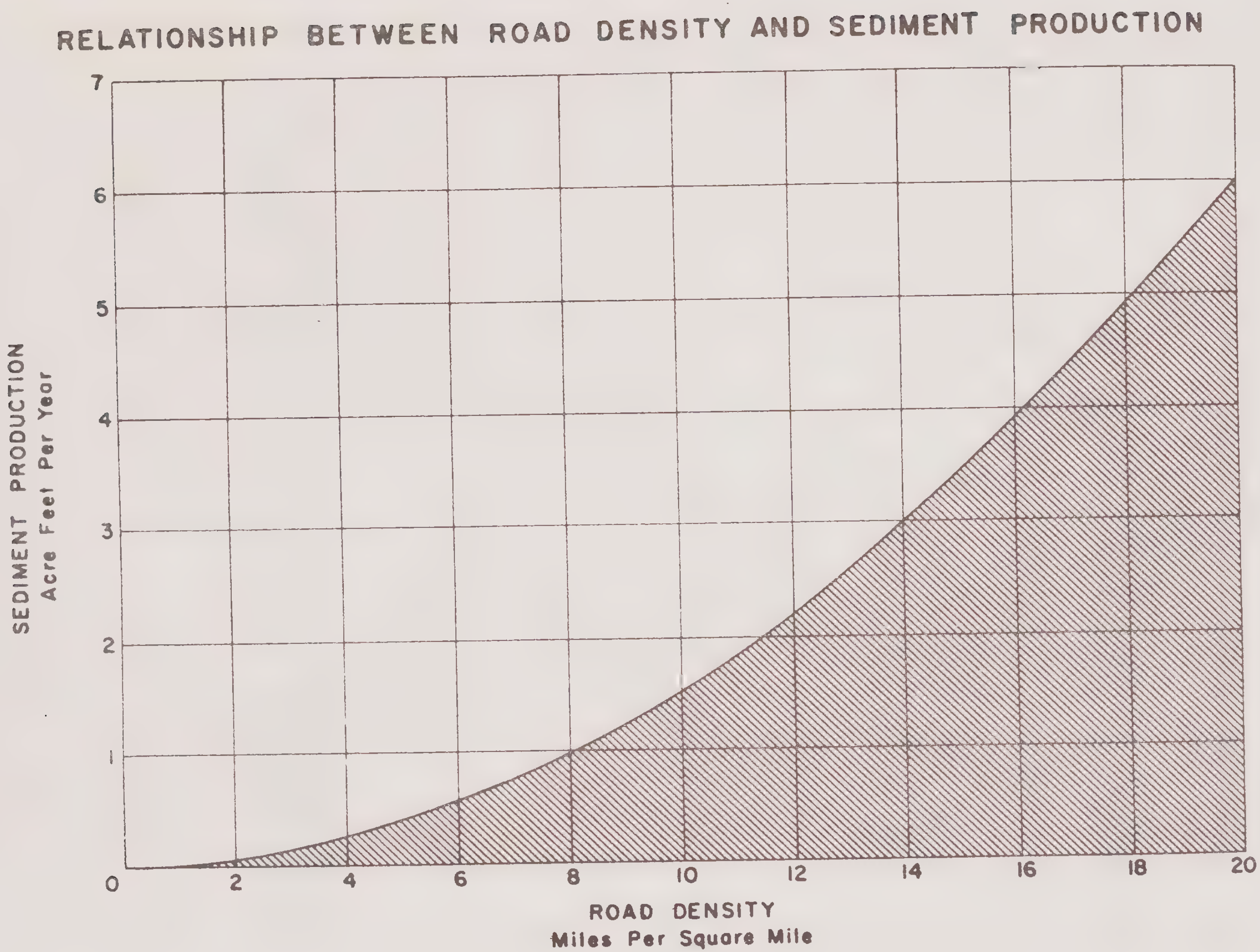

RELATIONSHIP BETWEEN ROAD DENSITY AND SEDIMENT PRODUCTION
SEDIMENT PRODUCTION
Acre Feet Per Year
0
1
2
3
4
5
6
7
2
4
6
8
10
12
14
16
18
20
ROAD DENSITY
Miles Per Square Mile

FIGURE II.F.2. CUT AND FILL AREA FOR ROADWAYS--20 FEET WIDE

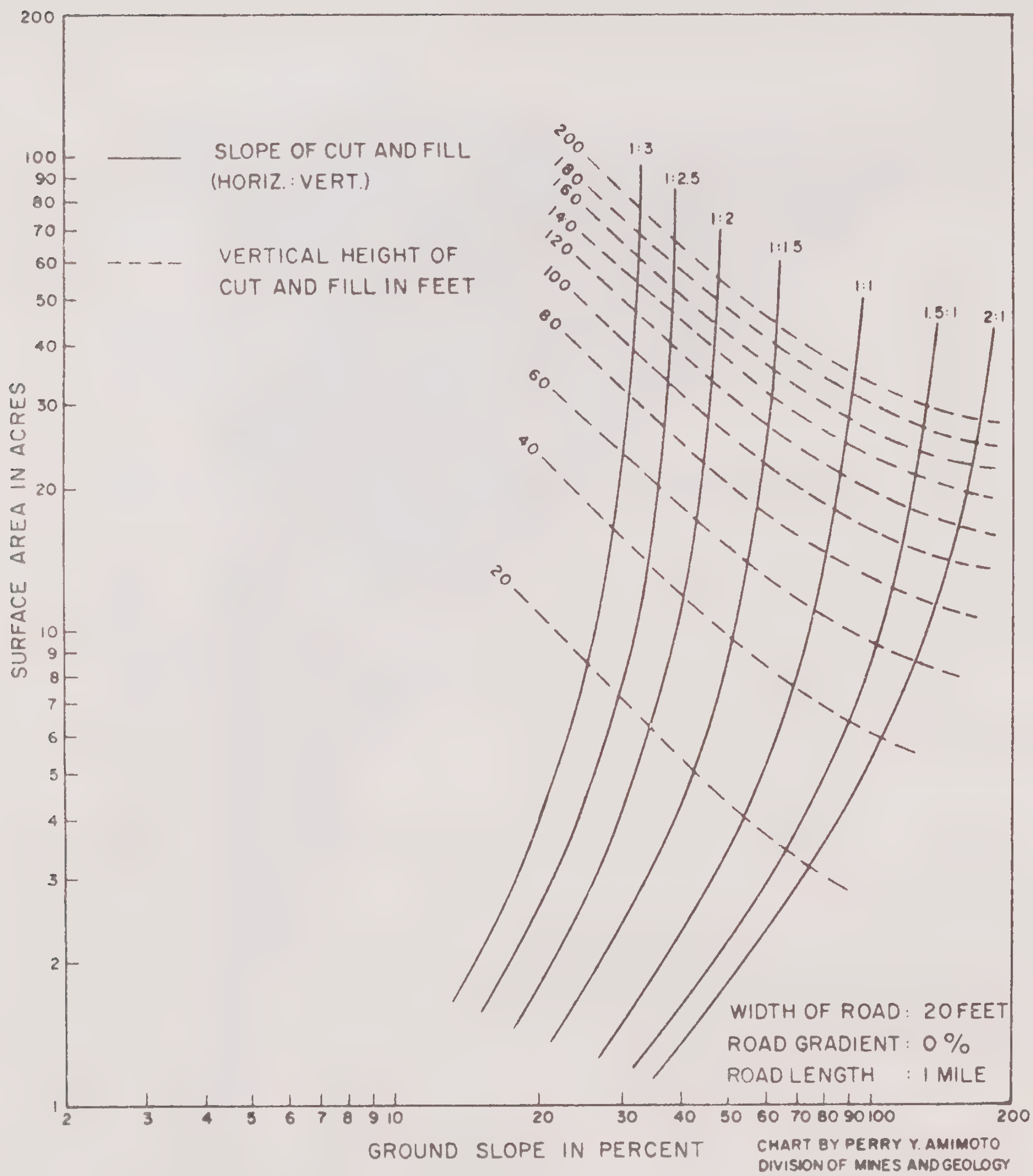


FIGURE II.F.3. CUT AND FILL AREA FOR ROADWAYS--60 FEET WIDE

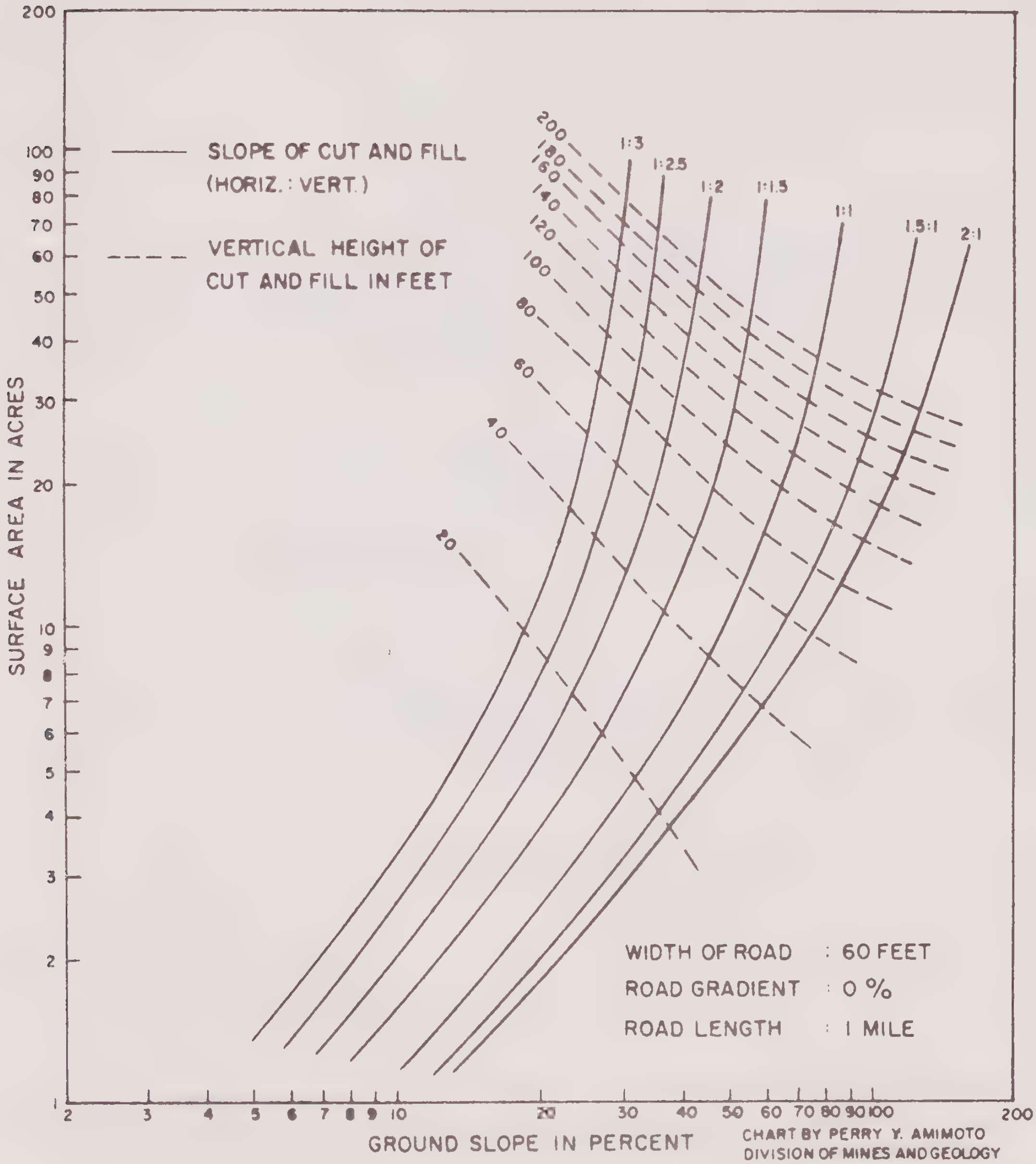
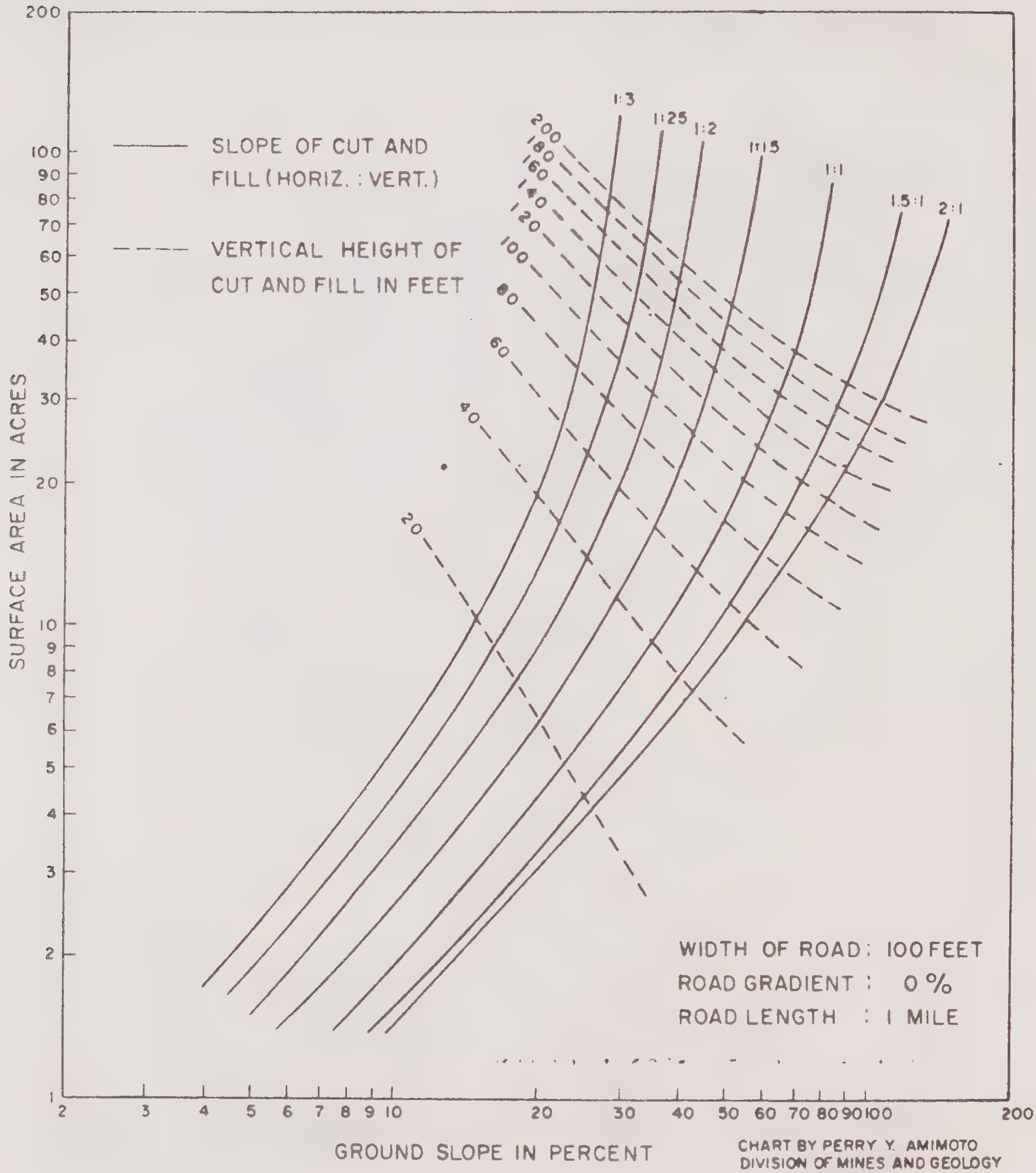


FIGURE II.F.4. CUT AND FILL AREA FOR ROADWAYS--100 FEET WIDE



Surface Runoff

Stormwater runoff can be estimated using the method by Victor Mockus and its variations. Briefly, these methods involve determining 1) a curve number based upon a given set of watershed characteristics such as surface storage, interception, and infiltration of rainwater; 2) the rainfall time distribution; and 3) the drainage area. These methods are particularly useful when quick, on-the-spot estimates of stormwater runoff are needed.

Runoff from areas of 2000 acres or less and having average slopes of less than 30 percent may be computed using the modification given by U.S. Soil Conservation Service, 1973. For areas exceeding these limits or when the computed peak discharge exceeds 2,000 CFS, the runoff may be computed using the method by Mockus (U.S. Soil Conservation Service, 1972).

Another common technique for predicting runoff is the rational method (Dunne and Leopold, 1978). This method is generally applicable to basins of 200) acres or less, but often areas as large as one square mile are assesses in this manner. It is assumed that a uniform rainfall intensity covers the entire area. The required inputs are:

Rational Runoff Coefficient (C):

A constant that takes into account such basin features as soil type, topography, surface roughness, vegetation, and land use. They are assumed not to vary during or between storms.

Rainfall Intensity (I):

This variable is needed in units of inches per hour.

Drainage Area (A):

This variable is needed in units of acres.

The result of the computation is:

Runoff (Q):

The units of runoff are cubic feet per second.

The equation used to compute runoff by this method is:

$$Q = CIA$$

At the beginning of a storm, runoff from distant parts of the basin will not have reached the discharge point where the basin's Q is monitored. After a period typical to each basin, a steady state flow or peak Q will occur. This is the Q predicted by the Rational Method. The initial period, known as the time of concentration, may be estimated using techniques described elsewhere (U.S. Soil Conservation Service, 1972).

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G. STANDARDS AND SAMPLE SPECIFICATIONS FOR EROSION AND SEDIMENT CONTROL MEASURES

This section contains standards and sample specifications for temporary and permanent measures to control construction-related erosion and sedimentation. The sample specifications provide control measure construction details used nationally by the USDA, Soil Conservation Service. Jurisdictions adopting a Manual of Standards as part of their local erosion control program may use this document as a guide subject to the following caveat. The standards and sample specifications that follow are based for the most part upon national standards and specifications. However, because of the variability of local and site-specific conditions (e.g., rainfall levels, soil conditions, etc.), a qualified professional should review and refine these standards and specifications before they are adopted for application in the local setting.

As used in this manual, a temporary control measure is a control measure installed during construction which is not a feature of the finished development. A "temporary and permanent" control measure can be used for both of the above cases.

Except for vegetative standards, which were prepared by ABAG, the standards and sample specifications contained in this section were prepared by the USDA, Soil Conservation Service. The language in these standards and specifications has been modified by ABAG for simplification and improved clarity, as recommended by ABAG's Water Quality Technical Advisory Committee.

The standards and sample specifications are interim recommendations intended for use during 1980 and 1981. During this period, these guidelines will be further refined after detailed analysis of their effectiveness in the Bay Area. It is expected that this manual will be continuously updated as more information becomes available.

The final version of this manual will contain schematics and drawings to illustrate the control measures.

1. TEMPORARY AND PERMANENT STANDARD FOR PLANTING EXPOSED SOILS

Definition

Planting fast growing vegetation, such as grasses, on erodible or eroding areas.

Purpose

To stabilize the soil by absorbing the impact of raindrops, reducing velocity of runoff and allowing precipitation to enter the soil; to provide both short and long term protection from erosion resulting from construction activities.

Scope

This practice shall include the furnishing of all labor, equipment, and materials and placing of fertilizer and seeds, including, when required, seedbed preparation and mulching.

Conditions Where This Practice Applies

On areas denuded of vegetation by construction activities and other highly erodible areas. Examples of applicable areas are cuts, fills, dams, dikes, levees, and denuded or gullied areas.

Design Considerations

The following should be considered when selecting the materials for exposed area planting:

- o erosion control effectiveness
  - fast growth
  - complete ground coverage
  - fibrous root mat
- o commercially available materials
- o high drought tolerance
- o low fire hazard
- o low fertilizer requirements
- o low cost to apply and maintain

The following should be considered when implementing exposed area planting:

(a) Seeds should be planted in time to:

- o germinate with the normally-occurring light, early season rains (0.5-1.0 inch storms)

- o establish a root mat capable of resisting the erosive force of a 2.0 inch storm (approximately 30 days after germination)

- o germinate and grow while temperatures are mild and daylight is relatively long (i.e., before November)

Optimum time for planting is before September 15. Planting by September 15 provides a 98% probability that seeds will be in the ground in time for the first germination-causing rain, and a 90% probability that the first erosive rain will not occur for over 45 days.

Planting by October 1 provides a 90% probability that seeds will be in the ground in time for the first germination-causing rain, and a 90% probability that the first erosive rain will not occur for over 30 days.

(b) The surface to be seeded should be roughened or broken up so that it can hold seed and permit germination. If a graded area is to be seeded later, it should not be smoothed by grading equipment, but left in a rough or serrated condition.

(c) The key factor in seeding is to cover the seeds with soil to the proper depth. Other factors to consider are the steepness of slope, size of area to be seeded and soil depth.

- o Small areas can best be hand seeded to provide uniform coverage. Breast seeders (or "belly-grinders") are very inexpensive. Labor effort is 2-3 hours/acre.

- o A seed drill works best on level areas. It should not be used on slopes greater than 3:1. When seed is drilled, fertilizer requirements may be reduced up to 50 percent.

- o Hydroseeding/hydromulching is most efficient for seeding steep slopes and shallow soils (such as cut slopes and slopes steeper than 2:1). The critical factor in hydroseeding/hydromulching is the ability of seeds and mulch material to adhere to the soil.

(d) Factors to consider before irrigating a planted area include:

- o drought tolerance of planted vegetation
- o size of area
- o steepness of slope
- o cost
- o time of year
- o equipment and technique
- o frequency
- o water availability

Irrigation is expensive (about \$1,000/acre/month). It is not necessary when using drought tolerant species, unless the area is particularly critical (such as a steep, erodible slope above a water supply reservoir). Once begun, it should be continued until plant cover is fully established. Ceasing irrigation after germination leaves seedlings vulnerable to being destroyed by drought. Excessive irrigation or other improper irrigation practices can be harmful.

(e) Application of mulch increases percentage of plant establishment and protects a disturbed site from erosive forces. Mulch helps hold fertilizer, seed and topsoil in place in the presence of wind, rain and runoff and maintains moisture near the soil surface. Commonly used mulches include straw, wood fiber, wood chips or bark, fabric or mats, soil and gravel.

The choice of mulch should be determined based on:

- effectiveness of materials
- size of area
- steepness of slope
- soil depth and surface hardness
- wind conditions
- availability of materials
- cost
- access to roadway and slope orientation (uphill or downhill)
- fire hazard
- weed growth considerations
- maintenance and repair costs.

Under the following conditions, straw is the best mulch material:

- slopes less steep than 2:1
- large areas accessible by straw blowing equipment within 50 feet
- fill slopes
- non-windy areas
- downhill or downwind applications
- near agricultural areas where straw is produced
- where fire hazard and weed growth are not critical factors
- where repair and revegetation would be costly (straw mulch is highly effective and should not require maintenance if properly applied).

Hydromulch is the best mulch material under these conditions:

- areas more than 50 feet from road access
- slopes steeper than 2:1
- cut slopes with shallow soil cover
- windy areas
- where straw is not available
- where fire hazard or weed growth are critical factors

(f) Straw mulch is highly effective if properly applied and should not require maintenance. While initial costs of applying hydromulch may be lower than straw mulch, repair and maintenance requirements are often greater for hydromulch. If seeding is done long before September 15, seed loss caused by birds and wind may be significant. Thus, planting during September may reduce maintenance costs (see also "Irrigation Considerations," above).

Slopes should be repaired and/or reseeded if the following conditions are observed:

- o erosion on bare areas of slope
- o sheet or rill erosion has occurred
- o sediment buildup at toe of slope

Unit Cost

Approximately $500 - 1,000/acre as of 1979.

Source and Reference

This standard was prepared by ABAG based upon material obtained from: USDA, Soil Conservation Service; SCS Plant Materials Center, Lockeford, CA; Burgess Kay, Wildland Seeding Specialist, Department of Agronomy and Range Science, University of California, Davis; Robert Crowell, Cagwin and Dorward Landscape Contractors and Engineers; U.S. Department of Commerce, National Weather Service.

Design Plans and Specification

Design Plans and Specifications for Critical Area Planting shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

Temporary and Permanent Planting Specifications for Exposed Soils

Vegetation cannot be expected to provide erosion and sediment control unless soil conditions, seedbed preparation, species, seeding rates, fertilization and mulching are provided for as specified below.

1. Soil Conditions - The soil on the site must meet the following criteria:

   A. The soil should contain no more than 70% sand (as defined by USDA, Soil Conservation Service). This is to provide enough available waterholding capacity to support plant growth.

   B. The soil shall have sufficient porous base (greater than 30%) to permit adequate root penetration, and provide for exchange of gases and water.

   C. The soil shall be free from any material harmful to plant growth.

   D. If these conditions are not met, top soil must be brought in that will meet the conditions. When top soil is brought in, it should be disked into the existing soil to provide for a good bond.

2. Seedbed preparation - The area to be seeded shall have a firm seedbed which has previously been roughened by scarifying, disking, harrowing, chiseling, or otherwise worked to a depth of 2 to 4 inches unless a roughened condition already exists. No implement shall be used that will create an excessive amount of downward movement of soil or clods on sloping areas. The seedbeds may be prepared at the time of completion of earth moving work.

3. Time of planting - To insure adequate stand establishment, seeding, fertilizing and mulching shall be done by September 15 of any year. Planting may be done earlier if irrigation is provided. If construction is not completed by October 1, temporary structural controls, such as sediment basins and sediment traps, may be used as interim control measures.

4. Seeding - Based on availability, seeding species and application rates should be from one of the following:

   A. Zorro annual fescue — 20# per acre
      Rose clover — 15# per acre

B.	Luna or Topar pubescent wheat grass, or Tegmar intermediate wheat grass	40# per acre broadcast or 20# per acre drilled
C.	Palestine or Burber orchard grass	30# per acre broadcast or 20# per acre drilled
	Blando brome	10# per acre broadcast or 5# per acre drilled
D.	Blando Brome	20# per acre broadcast
	Zorro annual fescue	10# per acre
	Wimmera 62 annual rye grass	20# per acre

All seed shall be delivered to the site tagged and labeled in accordance with the California Agricultural Code and shall be acceptable to the County Agricultural Commissioner.

Seed shall be of a quality which has a minimum pure live seed content of 80% (percent purity times percent germination), and weed seed shall not exceed 0.5% of the aggregate of pure live seed and other material. Zorro annual fescue shall have a minimum pure live seed content of 50% or more.

Seed shall be distributed uniformly over the seedbed by broadcasting by hand, using a hydroseeder or other approved equipment. Seed should be covered to a depth of one quarter inch to one half inch except when seed is applied by hydromulching. Seed shall not have a soil cover greater than one inch.

5. <u>Fertilizer</u> - Fertilizer shall be distributed uniformly over the seedbed at a rate of not less than 500# per acre. Fertilizer shall be applied in any way that will result in uniform distribution. Fertilizer shall be incorporated into the soil. Incorporation may be as part of the seedbed preparation or as part of the seeding operation. If fertilization is part of the seedbed preparation, it shall not be accomplished more than fifteen (15) days prior to seeding.

The fertilizer shall contain a minimum of 16% nitrogen, 20# available phosphoric acid, 0% water soluble potash and 15% sulfur. It shall be uniform in composition, dry and free flowing, pelleted or granular.

All fertilizer shall be delivered in unbroken or unopened containers, labeled in accordance with the applicable state regulations and bearing the warranty of the producer for the grade furnished.

Fertilizer may also be applied as a mix with seed and fiber in a slurry (see specification for hydromulching).

6. Mulching - A mulch covering shall be distributed uniformly over the surface of the seeded area. Mulching shall follow immediately after seeding.

   Straw mulch shall be of unrotted small grain straw applied at the rate of 4,000 # per acre. Mulch materials shall be relatively free of all noxious weeds. The mulch shall be applied by hand, blower or other suitable equipment. If the straw is applied with a blower, it shall be chopped at lengths not less than six (6) inches.

   The mulch will be anchored in place. The anchoring process may include using hand tools, mulching rollers, disks, nets, chemical tackifiers, or other similar types of suitable equipment.

   The above is applicable to slopes flatter than 2:1. For slopes steeper than 2:1 hydromulching should be employed.

7. Hydromulching - This method uses a hydroseeder to spread seed, fertilizer and mulch in a slurry.

   The hydroseeder shall be equipped with a built-in continuous agitation system of sufficient operating capacity to produce a homogeneous slurry and a discharge system which will apply the slurry to the slopes at a continuous and uniform rate. Seed shall not remain in the slurry longer than thirty (30) minutes. The slurry shall contain the required fertilizer and shall also contain wood fiber at the rate of 1,500 # of wood fiber per acre.

   The water used shall be potable water or class 1 or 2 agricultural irrigation water.

   The slurry shall be continuously mixed and shall be mixed at least 5 minutes after the last addition before application starts. The slurry shall be applied at a rate that is nonerosive and minimizes runoff.

8. Irrigation - Irrigation is not required. If irrigation is selected the following procedure shall be used. The surface inch of soil of all seeded areas shall be kept moist for the first 21 days after seeding. Moisture needs will be determined by visual observation. After 21 days the top 6-inches of soil shall be kept moist until the first major rainstorm (minimum 1.0"/24 hr. period). The moisture level will not be allowed to drop below 50% available moisture capacity.

Irrigation applications shall not exceed:

- 0.5 inches water applied per acre per irrigation on sandy soils.

- 1.0 inches water applied per acre per irrigation on loamy and clayey soils.

Irrigation water shall be potable or Class 1 or 2 agricultural irrigation water. Water shall be applied by sprinklers, or similar devices at a non-erosive rate using the above criteria as a guide.

9. <u>Maintenance</u> - Critical planting areas sites shall be inspected no more than 30 days after planting and no more than 30 days after the first rain. Follow-up inspections should occur between 60 and 90 days after the first inspection and once again in the spring. If the site is well stabilized (not yielding sediment) in the spring inspection, no further inspection shall be necessary.

   If the spring inspection, or any other inspection, reveals that the slope needs to be repaired in that the seed has not taken or erosion has taken place, slopes will be reseeded and/or repaired. The slope shall be smoothed over, including the filling of rills and/or gullies, before reseeding starts. The reseeding operation shall follow the specifications as given above.

<u>Source and Reference</u>

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

2. TEMPORARY DIVERSION OR PERIMETER DIKE STANDARD

Definition

Temporary ridge of compacted soil immediately above a cut or fill slope and constructed with sufficient grade to prevent drainage onto the slope.

Purpose

The purpose of a diversion dike and perimeter dike is to intercept storm runoff from small upland areas and divert it from exposed slopes to an acceptable outlet or to prevent sediment-laden storm runoff from leaving the construction site or disturbed area.

Scope

This standard applies to all earth fill structures constructed according to "Earth Dams and Reservoirs," USDA Soil Conservation Service, Technical Release No. 60, June 1976.

Conditions where this Practice Applies

The diversion dike is used for the period of construction at the top of newly constructed slopes to prevent excessive erosion until permanent drainage features are installed and/or slopes are stabilized.

Design Considerations

An engineered design is not required for diversion dikes and perimeter dikes. The following criteria should be considered:

1. Drainage area
2. Top width and height
3. Side slopes and grade
4. Stabilization
5. Outlet

Unit Cost Guide

Dike - typically $2.00 - $3.00/linear foot as of the Fall of 1979.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for installing diversion dikes and perimeter dikes should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Diversion of Perimeter Dike Specifications

Design Specifications

1. The drainage area shall be less than 5 acres (for larger drainage areas see Standard and Specifications for Diversion).

2. The top width shall be 2 feet minimum.

3. The height (compacted fill) shall be a minimum of 18 inches measured from the existing ground at the upslope toe to the top of the dike; 30 inches maximum height.

4. The side slopes shall be 2:1 or flatter.

5. The grade shall be dependent upon topography, but must have positive drainage (sufficient grade to drain) to an adequate outlet.

6. Where slope of channel (flow area) is:

   0% - 5% - stablilization may be required by the designer according to the needs of the site.

   Over 5% - stabilization shall be required.

   Stabilization shall be: (1) in accordance with Standard and Specifications for Diversion; or (2) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches in thickness and pressed into the soil. The lining shall extend up the upslope side of the dike at a height of at least 8 inches measured vertically from the upslope toe and shall extend at least 7 feet upslope from the upslope toe.

7. A. Diverted runoff from a protected or stabilized area shall outlet directly to an undisturbed stabilized area or into a level spreader or grade stabilization structure.

   B. Diverted runoff from a disturbed or exposed upland area shall be conveyed to a sediment trapping device such as a sediment trap or a sediment basin or to an area protected by any of these practices.

Construction Specifications - Temporary Diversion Dike

1. Compaction - All dikes shall be machine compacted with the tires or tracks going over at least 90% of the surface. There shall be a maximum of 6 inches of lift between each compaction.

2. Drainage - All diversion dikes shall have positive drainage to an adequate outlet.

3. Outlets -

   A. Diverted runoff from a protected or stabilized area shall outlet directly to an undisturbed stabilized area or into a level spreader or grade stabilization structure.

   B. Diverted runoff from a disturbed or exposed upland area shall be conveyed to a sediment trapping device such as a sediment trap or a sediment basin or to an area protected by any of these practices.

4. Stabilization - Stabilization, as specified by the plans, shall be: (1) in accordance with Standard and Specifications for Diversion, and the area to be stabilized shall be the channel (flow area); or (2) the flow area shall be lined with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 which is placed in a 3 inch thick layer and pressed into the soil.

5. Maintenance - Periodic inspection and required maintenance shall be provided.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

3. PERMANENT DIVERSION STANDARD

Definition

A channel with a supporting ridge on the lower side constructed across the slope.

Purpose

The purpose of a diversion is to intercept and divert excess water from areas to sites where it can be used or disposed of safely.

Scope

This standard and sample specification applies to the installation of all diversions except flood water diversions.

Conditions where this Practice Applies

1. Runoff from higher areas is or has the potential of damaging property, causing erosion, or interfering with, or preventing the establishment of vegetation on lower areas.

2. Surface and shallow subsurface flow caused by seepage is damaging sloping upland.

3. Runoff is in excess and available for diversion and use on near-by sites.

4. A diversion is required as part of a pollution abatement system.

5. A diversion is required to control erosion and runoff on urban and developing areas and construction sites.

In all of the above, the length of slopes is reduced so that the soil loss will be reduced to a minimum. Diversions shall not be substituted for terraces on land requiring terracing for erosion control. Avoid establishment on slopes greater than 15%. Diversion shall not be used below high sediment producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or for the diversions.

Design Considerations

Design considerations should include the following:

1. Capacity
2. Cross-section
3. Grade and velocity
4. Location
5. Protection against sedimentation
6. Outlets
7. Vegetation
8. Maintenance requirements

Unit Cost Guide

Diversion - typically $20.00-$25.00/linear foot as of the Fall of 1979.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for installing Diversions should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Permanent Diversion Specifications

Design Specifications

1. The constructed diversion shall have the capacity to carry, as a minimum, the peak discharge from a 10 year frequency rainfall event with a freeboard not less than 0.3 foot. Diversions designed to protect urban areas, buildings, and roads, and those designed to function in connection with other structures, shall have enough capacity to carry the peak runoff expected from a storm frequency consistent with the hazard involved.

2. The channel cross-section may be parabolic, V-shaped, or trapezoidal. The diversion shall be designed to have stable side slopes and shall not be steeper than 2:1 and shall be flat enough to insure ease of maintenance of the structure and its protective vegetative cover. The ridge height shall include a reasonable settlement factor. The ridge shall have a minimum top width of 4 feet at the design elevation. The minimum cross-section shall meet the specified dimensions. The top of the constructed ridge shall not be lower at any point than the design elevation plus specified overfill for settlement. A minimum of 0.3 foot freeboard will be provided.

3. Channel grades may be uniform or variable. Channel velocity shall not exceed that considered nonerosive for the soil and plant treatment.

4. The location of the diversion shall be determined by outlet conditions, topography, land use, cultural operations, soil type, seep planes (when seepage is a problem), and length of slope in the development layout.

5. If movement of sediment into the channel is a significant problem, a vegetated filter strip shall be used except where soil and/or climate preclude the use of such strips. Then, the design shall include extra capacity for sediment and be supported by supplemental structures, cultural or tillage practices, or special maintenance measures.

6. Each diversion must have an adequate outlet. The outlet may be a grassed waterway, a vegetated or paved area, a grade stabilization structure, a stable watercourse, or an underground outlet. The outlet must convey runoff to a point where outflow will not cause damage. Vegetated outlets shall be installed before the diversion construction to insure establishment of vegetative cover in the outlet channel. Underground outlets consist of inlet and underground conduit, and the release rate when combined with a storage is to be such that the design storm will not overtop the diversion ridge.

To prevent ponding in the diversion, the design elevation of the water surface in the diversion shall not be lower than the design elevation of the water surface in the outlet at their junction when both are operating at design flow.

7. Disturbed areas shall be established to grass as soon as practicable after construction. If the soils or climatic conditions preclude the use of vegetation and protection is needed, nonvegetative means, such as mulches or gravel, may be used. Seedbed preparation, seeding, fertilization, and mulching shall comply with recommendations supplied under Planting Exposed Soils.

<u>Construction Specifications</u> - Permanent Diversion

1. Site preparation - the foundation area for the embankment or ridge shall be stripped of all vegetation, brush or other objectionable material. Small gullies, ditches or depressions within the foundation area shall be filled and compacted. This will preclude interference with the proper functioning of the diversion.

2. Excavation - The channel shall be excavated to the neat lines and grades shown on the plans and/or as staked in the field. Excavated materials shall be used in the earth embankment or wasted to selected locations. Borrow shall be obtained at locations specified or shown on the drawings.

3. Underground conduits - If underground conduits are located under diversion ridges, mechanical compaction, water packing, and installation and backfill of conduit trenches shall be made in advance to allow adequate settlement. Materials used for the inlet and conduit shall be suitable for the purpose intended and shall meet the requirements as recommended under Subsurface Drains.

4. Earth fill -

   A. Material - All satisfactory fill material obtained from the excavated channel will be used to construct the embankment. Fill material containing brush, roots or other perishable or unsuitable materials shall not be used. Cobbles and rock fragments having a maximum dimension of more than 6 inches will be removed from the material. Gravel and sand will not be used to construct the fill unless mixed with clay material approved by the engineer.

   B. Soil moisture - The soil moisture shall be such that the material will form a firm ball when squeezed in the hand.

   C. Compaction - Compaction may be accomplished by the passage of the excavating equipment. The wheels or tracks of the excavating equipment must pass over 90% of the surface of each lift. Each lift shall not exceed 6 inches before compaction. Diversion ridges constructed across gullies or depressions shall also be compacted in the abovestated manner. The surface of the finished diversion shall be reasonably smooth and present a workmanlike appearance.

5. Vegetative requirements - A protective covering shall be established on all of the disturbed areas to the extent practicable under prevailing soil and climate conditions. Care will be taken during construction to avoid disturbance of vegetation outside the channel or embankment area. If it is necessary, top soil shall be stockpiled and spread over the excavations, and other areas, to facilitate revegetation.

6. Maintenance - A maintenance program should be established to maintain diversion capacity, storage, ridge height, and the outlets. Any hazards must be brought to the attention of the responsible person.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

4. TEMPORARY PERIMETER SWALE STANDARD

Definition

A temporary excavated drainageway located along the perimeter of the site or disturbed area.

Purpose

The purpose of a perimeter swale is to prevent offsite storm runoff from entering the disturbed area and to prevent sediment-laden storm runoff from leaving the construction site or disturbed area.

Scope

This standard applies to all temporary perimeter swales that have a drainage area less than 5 acres and that will be removed when the disturbed area is permanently stabilized.

Conditions where this Practice Applies

The perimeter swale is used for the period of construction at the perimeter of the disturbed area to transport sediment-laden water to a sediment trapping device such as a sediment trap or a sediment basin. This swale shall remain in place until the disturbed area is permanently stabilized. The perimeter swale is also used to prevent storm runoff from entering the disturbed area. This runoff shall be adequately handled to prevent damage due to flooding or erosion to adjacent property.

Design Considerations

Design considerations should include the following:

1. Location and possible permits necessary for construction
2. Drainage area
3. Bottom width of the perimeter swale
4. Depth of the perimeter swale
5. Side slope of the perimeter swale
6. Grade of the perimeter swale
7. Stabilization of the perimeter swale
8. Outlet from the perimeter swale

Unit Cost Guide

Swale - typically $8.00-$15.00/cubic yard as of the Fall of 1979 - dependent on nature of base material.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for installing Diversion Dikes should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Perimeter Swale Specifications

Design Specifications

1. The drainage area shall be less than 5 acres (for larger drainage areas, see Standard and Sample Specifications for Diversion or Grassed Waterway).

2. The bottom width shall be a minimum of 7 feet and the bottom shall be level.

3. The depth shall be a minimum of 1 foot.

4. The side slope shall be 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

5. The grade shall be dependent on topography, which shall have a minimum grade of 1% to an adequate outlet.

6. Where the slope of the channel (flow area) is 1 to 5%, stabilization may be required by the designer according to the needs of the site. Where the slope of the channel is greater than 5%, stabilization shall be required.

   Stabilization shall be in accordance with the Standard and Sample Specifications for Grassed Waterway; or by lining the flow area with stone that meets MSHA No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches in thickness and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel to a height at least 8 inches vertically above the bottom.

   At all points where several vehicle crossings per day will be made, the swale shall be stabilized according to number 2 above, except the stone lining shall be at least 6 inches in thickness for the whole width of the traffic crossing way.

7. A. Diverted runoff from a protected or stabilized upland area shall outlet directly onto an undisturbed area, level spreader, or into a grade stabilization structure.

   B. Diverted runoff from a disturbed or exposed upland area shall be conveyed to a sediment trapping device such as a sediment trap or a sediment basin or within an area protected by any of these practices.

Construction Specifications - Temporary Perimeter Swale

1. All trees, brush, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the swale.

2. The swale shall be excavated and/or shaped to line, grade, and cross-section as required to meet the criteria specified herein, and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed swale.

4. All earth removed and not needed in construction shall be spread or disposed of so it will not interfere with the functioning of the swale.

5. Perimeter swales shall have a minimum grade of 1% and the bottom shall be level.

6. A. Diverted runoff from a protected or stabilized upland area shall outlet directly onto an undisturbed stabilized area, level spreader, or into a grade stabilization structure.

   B. Diverted runoff from a disturbed or exposed upland area shall be conveyed to a sediment trapping device such as a sediment trap or sediment basin, or within an area protected by any of these practices.

7. Stabilization shall be: (1) in accordance with the Standard and Sample Specifications for Grassed Waterway; or (2) by lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches in thickness and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel height at least 8 inches vertically above the bottom.

8. Periodic inspection and required maintenance shall be provided to insure that the perimeter swale is functioning properly.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

5. TEMPORARY INTERCEPTOR SWALE STANDARD

Definition

A temporary excavated drainageway located across disturbed areas or rights-of-way.

Purpose

The purpose of an interceptor swale is to shorten the length of exposed slopes thereby reducing the potential for erosion, by intercepting storm runoff and diverting it to stabilized outlet or sediment trapping device.

Scope

This Standard applies to all interceptor swales in drainage areas for less than five acres. Any swale shall remain in place until the disturbed areas are permanently stabilized.

Conditions where this Practice Applies

Interceptor swales are constructed across disturbed rights-of-way such as for pipe lines and streets, or disturbed areas such as graded parking lots or land fills.

Design Considerations

The following design considerations should be used:

1. Drainage area
2. Bottom width
3. Depth
4. Side slopes
5. Grade
6. Stabilization
7. Traffic crossings
8. Spacing between swales

An interceptor swale should have an outlet that functions with a minimum of erosion.

Runoff should be conveyed to a sediment trapping device such as sediment trap or sediment basin.

The on-site location may need to be adjusted to meet field conditions in order to utilize the most suitable outlet.

Unit Cost Guide

Swale - typically \$8.00-\$15.00/cubic yard as of the Fall of 1979 - dependent on nature of base material.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plan and specifications for Interceptor Swales should be in keeping with this Standard, and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Interceptor Swale Specifications

Design Specifications

1. Drainage area - Less than 5 acres (for larger drainage areas see Standard and Specifications for Grassed Waterway).

2. Bottom width - 7 feet minimum and the bottom shall be level.

3. Depth - 1 foot minimum.

4. Side slopes - 2:1 or flatter (flat enough to allow construction traffic to cross if desired).

5. Grade - 1% to 3%, must have positive drainage (sufficient grade to drain) to an adequate outlet.

6. Stabilization - Not required by this standard but may be required by the designer according to the needs of the site. Stabilization shall be:

   A. In accordance with the Standard and Specifications for Grassed Waterway; or

   B. By lining the flow area with stone that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches in thickness and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel a height of at least 8 inches vertically from the bottom.

7. Traffic Crossing - At all points where several, or more, vehicle crossings per day will be made, the swale shall be stabilized according to B, except the stone lining shall be at least 6 inches in thickness for the full width of the traffic crossing roadway.

8. Spacing - If the slope of the right-of-way or disturbed area is greater than 10%, then the maximum distance between swales shall be 100 feet. If the slope is between 5% and 10%, the maximum distance shall be 200 feet. If the slope is less than 5%, the maximum distance shall be 300 feet.

Construction Specifications - Temporary Interceptor Swale

1. All trees, brush, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the swale.

2. The swale shall be excavated and/or shaped to line, grade, and cross-section as required to meet the criteria specified herein and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage in the completed swale.

4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the functioning of the swale.

5. Interceptor swales shall have a minimum grade of one percent and the bottom shall be level.

6. An interceptor swale shall have an outlet that functions with a minimum of erosion.

7. Runoff shall be conveyed to a sediment trapping device such as a sediment trap or a sediment basin.

8. The on-site location may need to be adjusted to meet field conditions in order to utilize the most suitable outlet.

9. Stabilization shall be:

   A. In accordance with the Standard and Specifications for Grassed Waterways; or

   B. By lining the flow area with a stone layer that meets MSHA size No. 2 or AASHTO M43 size No. 2 or 24 in a layer at least 3 inches in thickness and pressed into the soil. The lining shall extend across the bottom and up both sides of the channel in a height of at least 8 inches vertically above the bottom.

10. Periodic inspection and required maintenance shall be provided.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

6. TEMPORARY GRADE STABILIZATION STRUCTURE STANDARD

Definition

A temporary channel constructed of nonerodible material placed to extend from the top of a slope to the bottom of the slope.

Purpose

The purpose of a Grade Stabilization Structure is to convey concentrated surface runoff safely down slopes without causing erosion.

Scope

This standard applies to all types of grade stabilization structures up to a maximum drainage area of 36 acres. For drainage areas less than 5 acres see specifications for Pipe Slope Drain. For drainage areas between 5 and 36 acres see specification for Paved Chute or Flume.

Conditions where this Practice Applies

In areas where the concentration and flow velocity of water are such that structures are needed to stabilize the grade in channels or to control gully erosion.

Unit Cost Guide

Variable - dependent on materials, local topography and size.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design Plans and Specifications for constructing this Grade Stabilization Structure should be in keeping with this Standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Grade Stabilization Structure Specifications

Design Specifications

The quality of the materials shall be adequate to provide the stability and durability required to achieve the planned objective with appropriate factors of safety. A pipe slope drain or a paved chute or flume shall be used to convey surface runoff safely down slopes without causing erosion. The maximum allowable drainage area shall be five acres for a pipe slope drain, and a maximum allowable drainage area for a paved chute or flume shall be 36 acres.

Pipe Slope Drain

1. Design Criteria - Pipe Slope Drains are to be used as follows:

Size	Pipe/Tubing Diameter, D, (Inches)	Maximum Drainage Area (Acres)
PSD-12	12	0.5
PSD-18	18	1.5
PSD-21	21	2.5
PSD-24	24	3.5
PSD-30	30	5.5

2. Inlet - The height of the earth dike at the entrance to the pipe slope drain shall be equal to or greater than the diameter of the pipe, D+12 inches. See Standard Drawings.

3. Outlet - The pipe slope drain shall outlet onto a riprap apron and then into a stabilized area or stable water course. A sediment trapping device shall be used to trap sediment from any sediment laden water conveyed by the pipe slope drain.

Construction Specifications - Rigid Pipe Slope Drain

1. The inlet pipe shall have a slope of 3% or steeper.

2. The top of the earth dike over the inlet pipe, and those dikes carrying water to the pipe, shall be at least one foot higher at all points than the top of the inlet pipe.

3. The pipe shall be corrugated metal pipe with water tight connecting bands.

4. A riprap apron shall be provided at the outlet. This shall consist of 6-inch diameter stone placed as shown on the Standard Drawing.

5. The soil around and under the inlet pipe and entrance section shall be hand tamped in 4-inch lifts to the top of the earth dike.

6. Follow up inspection and any needed maintenance shall be performed after each storm.

Construction Specifications - Flexibile Pipe Slope Basin

1. The inlet pipe shall have a slope of 3% or steeper.

2. The top of the earth dike over the inlet pipe, and those dikes carrying water to the pipe, shall be at least 1-foot higher at all points than the top of the inlet pipe.

3. The inlet pipe shall be corrugated metal pipe with water tight connecting bands.

4. The flexible tubing shall be the same diameter as the inlet pipe and shall be constructed of durable material with hold down grommets spaced 10-inches on centers.

5. The flexible tubing shall be securely fastened to the corrugated metal pipe with metal strapping or water tight collars.

6. The flexible tubing shall be securely anchored to the slope by staking at grommets provided.

7. A riprap apron shall be provided at the outlet. This shall consist of 6-inch diameter stone placed as shown on the Standard Drawings.

8. The soil around and under the inlet pipe and entrance section shall be hand tamped in 4-inch lifts to the top of the earth dike.

9. Follow-up inspection and any needed maintenance shall be performed after each storm.

Paved Chute or Flume

1. Design Criteria

   Size Group A

   The height (H) of the dike at the entrance is at least 1.5 feet.
   The depth (D) of the chute down the slope is at least 8 inches.
   The length (L) of the inlet and outlet sections is 5 feet.

Size Group B

The height (H) of the dike at the entrance is at least 2 feet.
The depth (D) of the chute down the slope is at least 10 inches.
The length (L) of the inlet and outlet sections is 6 feet.

Each size group has various bottom widths and allowable drainage areas as shown below:

Size 1/	Bottom Width B, Feet	Maximum Drainage Area Acres	Size 1/	Bottom Width B, Feet	Maximum Drainage Area Acres
A-2	2	5	B-4	4	14
A-4	4	8	B-6	6	20
A-6	6	11	B-8	8	25
A-8	8	14	B-10	10	31
A-10	10	18	B-12	12	36

1/ The size is designated with a letter and a number, such as A-6, which means a chute or flume is size group A with a 6 foot bottom width. The selected size shall be shown on the plans.

2. Outlet - When a paved chute or flume of size group B is used, the velocity at its outfall shall be checked for erosion potential downstream.

Construction Specifications - Paved Chute or Flume

1. The structure shall be placed on undisturbed soil or on well compacted fill.

2. The cut or fill slope shall not be steeper than 2 horizontal to 1 vertical (2:1) and shall not be flatter than 20:1.

3. The top of the earth dike at the entrance, and those dikes carrying water to it, shall not be lower at any point than the top of the lining at the entrance of the structure.

4. The lining at the entrance to the structure shall extend the distance H above the lining crest shown on the Standard Drawings.

5. The lining shall be placed beginning at the lower end and proceeding up the slope to the upper end. The lining shall be well compacted and free of voids. The lining surface shall be reasonably smooth.

6. The entrance floor at the upper end of the structure shall have a slope toward the outlet of one quarter to one half inch per foot.

7. The cut off walls at the entrance and at the end of the discharge aprons shall be continuous with the lining.

8. The lining shall consist of Type 2 Portland cement concrete (3000 psi), Bituminous concrete or comparable nonerodible material.

9. An energy dissipator of adequate design shall be used to prevent erosion at the outlet.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

7. TEMPORARY SEDIMENT BASIN STANDARD

Definition

A temporary basin constructed to collect and store debris or sediment.

Purpose

To prevent undesirable deposition on bottomlands and developed areas; to trap sediment originating from construction sites; to preserve the capacity of reservoirs, ditches, canals, diversions, waterways and streams; and to abate or reduce pollution by providing basins for the deposition and storage of silt, sand, gravel, stone, and other wastes and detritus.

General

Sediment basins are created by constructing a barrier or dam across a drainageway at a suitable location to form a basin. During storm conditions this basin fills with runoff and acts as a detention area where the suspended sediment settles out due to the greatly reduced runoff velocity. The amount of trapped sediment is primarily a function of the particle size distribution of the incoming sediment, basin dimensions and detention time.

It is desirable to have a number of small sediment basins rather than one large basin.

Scope

This standard establishes the minimum acceptable quality standards for the design and construction of sediment basins if:

1. The earthfill structure is constructed according to "Earth Dams and Reservoirs," Technical Release No. 60, USDA, Soil Conservation Service, June 1976.

2. The effective height of the dam is less than 10 feet. The effective height is the difference in elevation measured from the emergency spillway crest to the lowest point in the cross-section taken along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.

3. The basin is to be removed within 12 months after the completion of construction on the site.

Conditions where this Practice Applies

A sediment basin applies where physical site conditions or land ownership restrictions preclude the installation of erosion control measures to adequately control runoff, erosion, and sedimentation. It may be used below construction operations which expose critical areas to erosion. It remains in effect until the disturbed area is protected against erosion by permanent stabilization.

Unit Cost Guide

Basin with dam and spillways - typically $500.00-$15,000 as of the Fall of 1979 - dependent on size, local topography and site conditions.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for installing Sediment Basins shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. For sediment basins that exceed the limits of this standard, and for alternate methods of design, consult the local USDA, Soil Conservation Service office or qualified engineers.

Plans and specifications shall comply with rules and regulations as set forth by the State Division of Safety of Dams, State Department of Fish and Game, and any other state or local agencies.

Sample Temporary Sediment Basin Specifications

Design and Construction Specifications

Formal design is required and must be in compliance with all state and local laws, ordinances and regulations. Plans for basins must be prepared by a licensed Civil Engineer.

Storage capacity - The volume of a sediment basin is measured from the bottom of the basin to the elevation of the crest of the principal spillway and shall be at least 130 cubic yards per acre of the total drainage area (1 watershed inch).

Sediment basins shall be cleaned out when the volume, as described above, is reduced by sedimentation to 55 cubic yards per acre of drainage area (0.4 watershed inches), except in no case shall the sediment level be permitted to build up higher than one foot below the principal spillway crest. This cleanout shall restore the original design volume to the sediment basin. The elevation corresponding tot he maximum allowable sediment level shall be determined and shall be stated in the design data as the distance below the top of the riser and shall be clearly marked on the riser.

The basin dimensions necessary to obtain the required basin volume, as stated above, shall be clearly shown on the plans to facilitate plan review, construction and inspection.

Site preparation - Borrow pits and the foundation area shall be cleared of trees, logs, stumps, roots, brush, boulders, sod and rubbish. If needed to establish vegetation, the topsoil and sod shall be stockpiled and spread on the completed dam and spillway. Foundation surfaces shall be sloped no steeper than 1:1. The foundation area shall be thoroughly scarified before the placement of fill material. The surface shall have moisture added or it shall be compacted if necessary so that the first layer of fill material can be compacted and bonded to the foundation.

Investigation - Pits, trenches, borings or other suitable means of investigation for sampling and classification of materials shall be conducted within the embankment foundation and borrow areas, and along the emergency spillway centerline.

Borrow areas shall be defined by no less than three pits, trenches, or borings. Borrow volumes available, excluding waste, should exceed the embankment volume by the percentage shown below:

Embankment Volume, Cu. Yds.	Percentage
Less than 2,500	35
2,500 to 7,500	50
7,500 to 12,000	75

Foundation cutoff - A cutoff of relatively impervious material shall be provided under the dam if necessary. The cutoff shall be located at or upstream from the centerline of the dam. It shall extend up the abutments as required and be deep enough to extend into a relatively impervious layer or provide for a stable dam when combined with seepage control. The cutoff trench shall have a bottom width adequate to accommodate the equipment used for excavation, backfill, and compaction operations, and shall have side slopes no steeper than 1:1.

Earth embankment -

1. All fill materials shall be obtained from approved borrow pits and from excavations required for other parts of the work. The selection, routing, and disposition of materials within the embankment shall be subject to the approval of the engineer. Fill materials shall contain no sod, brush, roots, or other perishable or unsuitable material. Cobbles and rock fragments having a maximum dimension of more than six inches shall be removed from the materials prior to compaction, and be disposed of or placed in areas designated by the engineer.

2. The placing and spreading of the fill material shall be started at the lowest point of the foundation. The fill shall be brought up in approximately horizontal layers parallel to the axis of the dam and of such thickness that the required compaction can be obtained with the equipment used.

   Fill placed around structures will be brought up at approximately uniform height on all sides of the structure so as not to put undue stresses upon the principal spillway.

   Where openings or section fills are called for in the embankment design, the slope of the bonding surfaces between the embankment in place and the embankment to be placed will not be steeper than 3:1. The bonding surface is to be treated the same as that specified for the foundation so as to insure a good bond with the new fill.

   The distribution and gradation of materials shall be such that there will be no lenses, pockets, streaks, or layers of material differing substantially in texture or gradation from the surrounding material. Where it is necessary to use materials of varying texture and gradation, the more impervious materials shall be placed in the center and upstream portions of the fill. Where zoned fills are specified of substantially differing materials, the zones shall be placed according to lines and grades shown on the drawings. The complete work shall conform to the lines, grades and elevations shown on the drawings. The complete work shall conform

to the lines, grades and elevations shown on the drawings or staked in the field.

3. The moisture content of fill material shall be such that the required degree of compaction can be obtained with the equipment used. The proper moisture content will be determined by inspection during the placement operation.

   As far as practicable, the material shall be brought to the proper water content in the borrow pit before excavation. Supplemental water, when required, may be applied by sprinkling the materials on the fill. Uniform distribution of the moisture shall be obtained by disking, blading or other approved method prior to compaction.

   Material that is too wet for proper compaction shall either be removed or allowed to dry before compaction.

4. Compaction shall meet the requirements of the method specified in the Construction Requirements and as specified below:

   A. Sheepsfoot roller - The maximum layer thickness shall be 8 inches before compaction. The roller shall have staggered, uniformly spaced tamping feet and be equipped with suitable cleaners. The weight of the roller shall not be less than 2,500 pounds per foot of width. The maximum speed of the compaction equipment shall be 3 miles per hour. The entire surface of each layer should receive 6 passes of this equipment to attain the necessary compaction. Adjustment of the number of passes may be necessary during compaction.

   B. Pneumatic field equipment - The maximum layer thickness before compaction shall be 6 inches. A loaded scraper may be considered a pneumatic roller. The wheels of this equipment must pass over 90% of the surface of the lift before a new lift is placed.

   C. Track laying equipment - The maximum layer thickness shall be 4 inches. The tracks of the equipment must pass over 90% of the surface of the lift before a new lift is placed.

   D. Compaction shall result in densities equal to or greater than 95% of the maximum obtained by laboratory compaction at optimum moisture of like soils in accordance with the procedure given in ASTM D-698, Method A.

   E. Compaction shall result in densities equal to or greater than 90% of the maximum obtained by laboratory compaction at optimum moisture of like soils in accordance with the procedure given in ASTM D-1557, Method A.

   Heavy compaction equipment shall not be operated within 2 feet of any structure. Hand directed tampers or compactors shall be used on areas not accessible to heavy compaction equipment, and within 2 feet of any structure. Fills compacted in this manner shall be

placed in layers not greater than 4 inches in thickness before compaction, and shall meet the same density requirement as for the adjacent area.

Fill not meeting the specified requirements shall be reworked or removed and replaced by acceptable fill.

The passage of heavy equipment will not be allowed over any type of conduit until the compacted backfill has been placed over the top surface of the structure equal to one-half the clear span width of the pipe, or 2 feet, whichever is greater.

5. The minimum topwidth of the dam will be determined by the following equation:

$$W = \frac{H+35}{5}$$

H is the effective height of the dam; W is the minimum width; units are feet.

6. The upstream side slope of the settled embankments shall not be less than 3:1, and the downstream slope not steeper than 2:1. All slopes must be designed to be stable, even if flatter side slopes are required.

7. The minimum elevation of the top of the settled embankment shall be 1 foot above the water surface in the basin with the emergency spillway flowing at design depth. The minimum difference in elevation between the crest of the emergency spillway and the settled top of the dam shall be 3 feet.

The design height of the dam shall be increased by the amount needed to insure that after settlement the height of the dam equals or exceeds the design height. This increase shall not be less than 5%, except where detailed soil testing and laboratory analysis show a lesser amount is adequate.

Principal Spillway - A pipe conduit, with needed appurtenances, shall be placed under or through the dam except where other types of spillways are used or where the rate and duration of flow can be safely handled by a vegetated earth spillway. Where a pipe conduit is to be installed, the following applies:

1. Control valves shall be installed on the upstream end. No valve shall be installed where the conduit serves the single purpose of carrying flow from a flashboard riser.

2. It shall be placed in a trench excavated in firm foundation, or in compacted fill not more than 3 feet above firm foundation.

3. Anti-seep collars shall be installed around all conduits within the normal saturation zone, the upstream two thirds of the conduit length, or to positive embankment drainage facilities. These collars shall extend beyond the pipe or encasement not less than 18 inches in all directions except where a water-tight seal can be obtained by tying the collar into firm rock. The maximum spacing of collars shall not exceed 15 feet.

4. The conduit shall have a minimum diameter of 4 inches if smooth, and 6 inches if corrugated. It shall conform to the requirements of Federal Specifications WW-P-402 or WW-P-405, as appropriate, and its use will be compatible with any guidelines provided by the manufacturer. Anti-seep collars shall be of material that is compatible with the conduit, and shall be installed so that they are water-tight.

5. A riser (vertical pipe) shall be joined to the principal spillway conduit at the upstream end, and will be placed in the pool rather than in the fill, and shall meet the following:

   A. The crest evaluation of the highest flashboard of the riser shall be a minimum of 1 foot below the crest elevation of the emergency spillway. Flashboards shall be made of redwood and be a minimum of 3 inches thick.

   B. The riser shall be a half-round corrugated metal pipe with support braces spaced not more than 36 inches apart. Minimum thickness is 12 gauge.

   C. The riser shall have a base with sufficient weight to prevent flotation of the riser.

6. Riprap or another approved material shall be installed at the downstream end of the conduit and at least 5 feet away from the toe of the embankment in order to dissipate the energy of the effluent and to negate the hazard of soil erosion.

Emergency Spillway - An emergency spillway must be provided for each dam, unless the principal spillway is large enough to pass the discharge and trash from a 50-year, 24-hour storm without overtopping the dam. The minimum capacity of the emergency spillway be adequate to safely pass the peak flow of the aforementioned storm. The passage of flow must be of a safe velocity to a point downstream where the dam will not be endangered.

Constructed spillways shall be trapezoidal, with side slopes of 2:1, and shall be located in undisturbed or compacted earth. The side slopes shall be stable. The inlet channel of the spillway shall be level for the distance needed to protect and maintain the crest elevation of the spillway. The inlet

channel may be curved to fit existing topography. The grade of the exit channel of a constructed spillway shall fall within the range established by discharge requirements and permissible velocities. Where spillway levees or training dikes are required to protect the downstream toe of the fill, they shall have side slopes not steeper than 3:1. The minimum top width of spillway training dikes or levees is 12 feet.

Protection and Maintenance - A protective cover of vegetation shall be established on all exposed surfaces of the embankment, spillway and borrow area if soil and climatic conditions permit. If soil or climatic conditions preclude the use of vegetation and protection is needed, nonvegetative means, such as mulches or gravel, may be used. The embankment and spillway shall be fenced, if necessary, to protect the vegetation.

Seedbed preparation, seeding, fertilizing, and mulching shall comply with the technical specifications of the USDA, Soil Conservation Service.

If a basin is adjacent to a residential area and is determined to be a safety hazard, it shall be fenced.

The basin shall be inspected after each storm. As the basin removes sediment, the remaining storage capacity is continually reduced. It shall be cleaned. Sediment must be disposed of or stabilized in a manner that will preclude its return to downstream areas.

Information Required for all Sediment Basins

1. Planned location of the dam and basin area
2. Plan view of dam and basin
3. Cross-section of dam and emergency spillway; profile of emergency spillway
4. Runoff calculation
5. Capacity calculations

    A. Total storage required
    B. Total storage available
    C. Cleanout depth

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

8. TEMPORARY SEDIMENT TRAP STANDARD

Definition

A small temporary basin formed by excavation and/or an embankment to intercept sediment laden runoff and to trap and retain the sediment.

Purpose

The purpose of a sediment trap is to intercept sediment laden runoff and trap the sediment in order to protect drainageways, properties, and rights-of-way below the sediment trap from sedimentation.

Scope

This standard applies to all sediment traps that are temporary in nature and whose drainage area is less than 5 acres. For any trap whose design exceeds this standard see Sediment Basin.

Conditions where this Practice Applies

A sediment trap is usually installed in a drainageway, at a storm drain inlet, or at other points of discharge from the disturbed area.

Design Considerations

Design considerations should include the following:

1. Drainage area in acres.
2. Design capacity.
3. Cleanout intervals.
4. Embankment and/or excavation specifications.
5. Outlet design.
6. Type of sediment trap as to be compatible with the existing topography.

Unit Cost Guide

Trap - typically $500.00-$2,000.00 in the Fall of 1979 - dependent on size, local topography and nature of base material.

Sources and References

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specification

Design plans and Specifications for Sediment Traps should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Sediment Trap Specifications

Design Specifications (applies to all sediment traps)

1. The drainage area for a sediment trap shall be less than 5 acres.

   The sediment trap should be located to obtain the maximum storage benefit from the terrain, for ease of cleanout and disposal of the trapped sediment and to minimize interference with construction activities.

2. The volume of a sediment trap as measured at the elevation of the crest of the outlet shall be at least 3,500 cubic feet per acre of drainage area. The volume of the trap shall be calculated using standard mathematical procedures. The volume of a natural basin may be approximated by the equation; Volume (cu. ft.) = 0.4 x surface area (sq. ft.) x maximum depth (ft).

3. Sediment shall be removed and the trap restored to its original dimensions when the sediment has accumulated to 1/2 of the design depth of the trap. Sediment removed from the trap shall be deposited in a suitable area and in such manner that it will not erode.

4. All embankments for sediment traps shall not exceed 5 feet in height as measured at the low point of the original ground along the centerline of the embankment. Embankments shall have a minimum 4 foot wide top, and side slopes 2:1 or flatter. The embankment shall be compacted by traversing with equipment while it is being constructed. Equipment shall compact at least 90% of the surface area.

5. All excavation operations shall be carried out in such a manner that erosion and water pollution shall be minimal. Any excavated portion of sediment trap shall have 2:1 or flatter slopes.

6. Outlets shall be designed, constructed and maintained in such a manner that sediment does not leave the trap and that erosion of the outlet does not occur. A trap may have several different outlets with each outlet conveying part of the flow based on the criteria below and the combined outlet capacity shall meet that criteria. For example, a 12 foot earth outlet (adequate for 2 acres) and a 12" pipe outlet (adequate for 1 acre) could be used for a three acre drainage area.

7. If the sediment trap uses an earth outlet, the outlet width (ft) shall be equal to six times the drainage area (acres). If an embankment is used, the outlet crest shall be at least one foot

below the top of the embankment. The outlet shall be free of any restriction to flow. See details for Earth Outlet Sediment Trap on the Standard Drawing.

8. If the sediment trap uses a pipe outlet, the outlet pipe and riser shall be made of corrugated metal. The riser diameter shall be of the same or larger diameter than the pipe. The top of the embankment shall be at least 1-1/2 feet above the crest of the riser. At least the top 2/3 of the riser shall be perforated with 1/2" diameter holes spaced 8 inches vertically and 10-12 inches horizontally. All pipe connections shall be watertight.

   Select pipe diameter from the following table:

Min. Pipe Diameter	Max. Drainage Area Acres
12"	1
18"	2
21"	3
24"	4
30"	5

   See details for Pipe Outlet Sediment Trap on Standard Drawing.

9. If the sediment trap uses a stone outlet, the outlet will be over a level stone section. The stone outlet for a sediment trap differs from that for a stone outlet structure because of the intentional ponding of water behind the stone. To provide for a ponding area a relatively impervious core (e.g., - timber, concrete block or straw bales) is placed in the stone. The core shall be covered by 6" of stone.

   The minimum length (feet) of the outlet shall be equal to 6 times the drainage area (acres). The crest of the outlet, top of stone, shall be at least 1 foot below the top of the embankment. The crushed stone used in the outlet shall meet AASHTO designation M43, Size No. 2 or 24 or its equivalent such as MSHA No. 2. Gravel meeting the above gradation may be used if crushed stone is not available. For details on the Stone Outlet Sediment Trap see Standard Drawing.

10. The sediment trap uses a storm inlet as its outlet. The storm drain and inlet should be placed so as not to interfere with construction activities. See details for Storm Inlet Sediment Trap on the Standard Drawing.

Construction Specifications - Temporary Sediment Trap

1. Area under embankment shall be cleared, grubbed, and stripped of any vegetation and root mat. The pool area shall be cleared.

2. The fill material for the embankment shall be free of roots or other woody vegetation as well as oversized stones, rocks, organic material or other objectionable material. The embankment shall be compacted by traversing with equipment while it is being constructed.

3. Sediment shall be removed and trap restored to its original dimensions when the sediment has accumulated to 1/2 the design depth of the trap. Removed sediment shall be deposited in a suitable area and in such a manner that it will not erode.

4. The structure shall be inspected after each rain and repairs made as needed.

5. Construction operations shall be carried out in such a manner that erosion and water pollution are minimized.

6. The structure shall be removed and area stabilized when the remaining drainage area has been properly stabilized.

7. All cut and fill slopes shall be 2:1 or flatter.

8. When a riser is used, all pipe joints shall be watertight.

9. When a riser is used, at least the top 2/3 of the riser shall be perforated with 1/2-inch diameter holes spaced 8 inches vertically and 10-12 inches horizontally.

10. When a pipe outlet is used, fill material around the pipe spillway shall be hand-compacted in 4-inch layers. A minimum of two feet of hand-compacted backfill shall be placed over the pipe spillway before crossing it with construction equipment.

11. When an earth or stone outlet is used, outlet crest elevation shall be at least one foot below the top of the embankment. Pipe outlets shall be at least 1.5 feet below the top of the embankment.

12. When a crushed stone outlet is used, the crushed stone used in the outlet shall meet AASHTO designation M43, Size No. 2 or 24 or its equivalent such as MSHA No. 2. Gravel, meeting the above gradation, may be used if crushed stone is not available. Crusher run is not acceptable.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

9. TEMPORARY STABILIZED CONSTRUCTION ENTRANCE STANDARD

Definition

A stabilized pad of crushed stone located at any point where traffic will be entering or leaving a construction site to or from a public right-of-way, street, alley, sidewalk or parking area.

Purpose

The purpose of a stabilized construction entrance is to reduce or eliminate the tracking or flowing of sediment onto public rights-of-way.

Scope

This standard applies to all temporary stabilized construction entrances that are to be removed within 12 months after the completion of construction.

Conditions where this Practice Applies

A Stabilized Construction Entrance applies to all points of construction ingress and egress.

Design Considerations

Design considerations should include the following:

1. The material to be used in the construction of the pad.
2. All the dimensions of the pad.
3. Maintenance of the pad.

Unit Cost Guide

Entrance - typically $4,000-$5,000 in the Fall of 1979.

Sources and References

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for Stabilized Construction Entrance should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Temporary Stabilized Construction Entrance Specifications

Design Specifications

1. The material for construction of the pad shall be stone which meets AASHTO designation M43, size No. 2 or MSHA size No. 2.

2. The thickness of the pad shall not be less than 8 inches.

3. The width of the pad shall not be less than full width of all points of ingress or egress.

4. The length of the pad shall be as required, but not less than 50 feet.

5. The entrance shall be maintained in a condition which will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic top dressing with additional stone as conditions demand and repair and/or cleanout of any measures used to trap sediment. All sediment spilled, dropped, washed or tracked onto public rights-of-way must be removed immediately.

   When necessary, wheels must be cleaned to remove sediment prior to entrance onto public rights-of-way. When washing is required, it shall be done on an area stabilized with crushed stone which drains into an approved sediment trap or sediment basin. All sediment shall be prevented from entering any storm drain, ditch, or watercourse through use of sand bags, gravel, boards or other approved methods.

Construction Specifications - Temporary Stabilized Construction Entrance

1. Stone size shall be AASHTO designation M43, size No. 2 or MSHA size No. 2. Use crushed stone.

2. Length shall be as effective, but not less than 50 feet.

3. The thickness shall be not less than 8 inches.

4. The width shall not be less than the full width of all points of ingress or egress.

5. When necessary, wheels shall be cleaned to remove sediment prior to entrance onto public rights-of-way. When washing is required, it shall be done on an area stabilized with crushed stone which drains into an approved sediment trap or sediment basin. All sediment shall be prevented from entering any storm drain, ditch, or watercourse through the use of sand bags, gravel, boards or other approved methods.

6. The entrance shall be maintained in a condition which will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic top dressing with additional stone as conditions demand and repair and/or cleanout of any measures used to trap sediment. All sediment spilled, dropped, washed or tracked onto public rights-of-way must be removed immediately.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

10. TEMPORARY STRAW BALE DIKE STANDARD

Definition

A temporary barrier with a life expectancy of 3 months or less, installed across or at the toe of a slope.

Purpose

The purpose of a straw bale dike is to intercept and detain small amounts of sediment from unprotected areas of limited extent.

Scope

This standard applies to all straw bale dikes that are to be removed within 3 months after construction.

Conditions where this Practice Applies

The Straw Bale Dike is used where:

1. No other practice is feasible, and

2. There is no concentration of water in a channel or other drainageway above the barrier; and

3. Erosion would occur in the form of sheet and rill erosion, and

4. Contributing drainage area is less than 1/2 acre and the length of slope above the dike is less than 100 feet. The practice may also be used for a lone single-family lot if the slope is less than 15%. The contributing drainage area in this instance shall be less than 1 acre and the length above the dike shall be less than 200 feet.

Design Considerations

A design is not required. All bales shall be placed on the contour and shall be either wire bound or nylon string tied and staked in place. See the Standard Drawing for details. The life expectancy of straw bale dikes can be extended when used with filter fabric.

Unit Costs

Straw dike - approximately $2.00/linear foot as of the Fall of 1979.

Sources and References

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Sample Temporary Straw Bale Dike Specifications

Construction Specifications

1. Bales shall be placed in a row with ends tightly abutting the adjacent bales.

2. Each bale shall be embedded in the soil a minimum of 4".

3. Bales shall be securely anchored in place by stakes or re-bars driven through the bales. The first stake in each bale shall be driven toward previously laid bale to force bales together.

4. Inspection shall be after each storm and repair or replacement shall be made promptly as needed.

5. Bales shall be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

11. PERMANENT GRASSED WATERWAY STANDARD

Definition

A natural or constructed waterway or outlet, shaped or graded, and established in suitable vegetation for the safe transport of runoff.

Purpose

To provide for the transport of excess surface water from terraces, diversions, subdivisions, or natural drainage areas without causing erosion or flooding.

Scope

This standard applies to the natural or constructed channels that are to be lined with vegetation and used for water conveyance in a wide and shallow flow.

Conditions where this Practice Applies

All sites where added capacity, vegetative protection, or both, are required to control erosion resulting from concentrated runoff and where such control can be achieved by the use of these practices alone or in combination with others.

Design Considerations

Design for every grassed waterway shall include the following:

1. Capacity
2. Allowable water velocity
3. Width
4. Depth
5. Drainage
6. Outlets
7. Maintenance
8. Access control for public safety

Unit Cost Guide

Grass Establishment - typically $1.00-$1.50/square foot in the Fall of 1979.

Sources and References

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for Grassed Waterways or Outlets should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Sample Permanent Grassed Waterway Specifications

Design Specifications

1. The minimum capacity shall be that required to confine the peak rate of runoff expected from a 25-year frequency rainfall event, or a higher frequency, corresponding to the hazard involved. This requirement for confinement is waived on slopes of less than 1% where out-of-bank flow will not cause erosion or property damage.

   Peak rates of runoff values used in determining the capacity requirements shall be as outlined in Chapter 2, "Estimating Runoff", Engineering Field Manual For Conservation Practices, USDA, Soil Conservation Service, or by other accepted methods.

   Where there is base flow (winter), it shall be handled by a stone center, subsurface drain, or other suitable means since sustained wetness usually prevents adequate vegetative cover. The cross-sectional area of the stone center or subsurface drain to be provided shall be determined by using a flow rate of 0.1 cfs/acre or by actual measurement of the maximum base flow.

2. Velocity - Maximum permissible velocities of flow for the stated conditions of stabilization are shown in the following table:

Maximum Permissible Design Velocities

Cover	Range of Channel Gradient (percent)	Permissible Velocity (Feet per second)
A. Vegetative 1/		
1. Tufcote, Tifway Santa Anna or Coastal Bermudagrass	0 to 5.0	6
	5.1 to 10.0	5
	over 10.0	4
2. Alta or Goar tall fescue	0 to 5.0	5
	5.0 to 10.0	4
	over 10.0	3
3. Annuals 2/ Small grain (rye, oats, barley, millet) Ryegrass	0 to 5.0	2.5
B. Vegetative with Stone Center for base flow		As determined for the vegetative portion from "A" above.

1/ To be used only below stabilized or protected areas.
2/ Annuals - Use only as temporary protection until permanent vegetation is established.

3. Cross-Section - The design water surface elevation of a waterway receiving water from diversions or other tributary channels shall be equal to or less than the design water surface elevation in the diversion or other tributary channels.

   The top width of parabolic waterways shall not exceed 30 feet and the bottom width of trapezoidal waterways shall not exceed 15 feet unless multiple or divided waterways, stone center, or other means are provided to control meandering of low flows.

   The design procedures for parabolic and trapezoidal channels are in Appendix A.

   See Standard Drawings for detail.

4. Outlets - Each waterway shall have a stable outlet. The outlet may be another waterway, a stabilized open channel, grade stabilization structure, etc. In all cases, the outlet must discharge in such a manner as not to cause erosion. Outlets shall be constructed and stabilized prior to the operation of the waterway.

5. Drainage - Subsurface drainage measures shall be provided for sites having high water tables or seepage problems, except where water tolerant vegetation can be used.

   Where there is base flow, a stone center, a subsurface drain or other suitable means shall be required.

6. Irrigation - An adequate irrigation system shall be provided to insure the success of the Grassed Waterway.

7. Stabilization - Waterways shall be stabilized in accordance with the appropriate Standard and Specifications for Vegetative Practices.

<u>Construction Specifications</u> - Permanent Grassed Waterway

1. All trees, brush, stumps, obstructions, and other objectionable material shall be removed and disposed of so as not to interfere with the proper functioning of the waterway.

2. The waterway shall be excavated or shaped to line, grade, and cross-section as required to meet the criteria specified herein, and be free of bank projections or other irregularities which will impede normal flow.

3. Fills shall be compacted as needed to prevent unequal settlement that would cause damage to the completed waterway.

4. All earth removed and not needed in construction shall be spread or disposed of so that it will not interfere with the function of the waterway.

5. Stabilization shall be done according to the appropriate Standard and Specifications for Vegetative Practices.

A. For design velocities of less than 3.5 ft./sec., seeding and mulching may be used for the establishment of the vegetation. It is recommended that, when conditions permit, temporary diversions or other means should be used to prevent water from entering the waterway during the establishment of the vegetation.

B. For design velocities of more than 3.5 ft./sec., the waterway shall be stabilized with sod, with seeding protected by jute or excelsior matting or with seeding and mulches including temporary division of the water until the vegetation is established.

C. Structural - Vegetative Protection

(1) Stone Center for base flow - Stone centers shall be constructed as shown in the Standard Drawing.

The Stone Center portion shall be stabilized with riprap according to Standard and Specifications for Riprap.

(2) Subsurface drain for the base flow shall be constructed as shown on the Standard Drawing and as specified in the Standard and Specifications for Subsurface Drain.

(3) Gabion mattress channel liners may be used for base flow, design flow and for subsurface drainage.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

12. PERMANENT LINED WATERWAY OR OUTLET STANDARD

Definition

A waterway or outlet having an erosion-resistant lining of concrete, stone, or other permanent material. The lined section extend up the side slopes to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected.

Purpose

To provide for safe conveyance of runoff from other erosion or sediment control structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.

Scope

This standard applies to waterways or outlets having linings or nonreinforced, cast in place concrete; flagstone mortared in place; rock riprap; or similar permanent linings. It does not apply to irrigation water conveyance, grassed waterways with stone centers or small lined sections to carry prolonged low flows. The maximum capacity of the waterway flowing at designed depth shall not exceed 200 cfs.

Conditions where this Practice Applies

This practice applies if the following or similar conditions exist:

1. Concentrated runoff is such that a lining is needed to control erosion;

2. Steep grades, wetness, prolonged base flow, seepage, or piping would cause erosion.

3. The location is such that use by people or animals preclude use of vegetated waterways or outlets.

4. High-value property or adjacent facilities warrant the extra cost to contain design runoff in a limited space.

5. Soils are highly erosive or other soil or climatic conditions preclude using vegetation.

6. Installation of nonreinforced concrete or mortared flagstone linings, shall be made only on low shrink-swell soils that are well drained or where subgrade drainage facilities are installed.

Design Considerations

The design should include specifications for capacity, water velocity, cross-section, freeboard, side slope, lining thickness, related structures, filters or bedding, concrete or mortar, contraction joints, riprap or flagstone and maintenance.

Unit Cost Guide

Concrete - typically $100.00-$200.00/cubic yard in the Fall of 1979 - dependent on type needed.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for constructing lined waterways or outlets should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purposes.

Permanent Lined Waterway of Outlet Sample Specifications

Design Specifications

1. The minimum capacity shall be adequate to carry the peak rate of runoff from a 25-year frequency storm. Velocity shall be computed by using Manning's formula with a coefficient of roughness "n" as follows:

Lining	"n" Value
Concrete	
Trowel Finish	0.012 - .014
Float Finish	.013 - .017
Gunite	.016 - .022
Flagstone	.020 - .025
Riprap	Determine from figure 1

2. Maximum design velocity shall be as shown in figure 2. Except for short transition sections, flow in the range of 0.7 to 1.3 of the critical slope must be avoided unless the channel is straight. Velocities exceeding critical shall be restricted to straight reaches.

   Waterways or outlets with velocities exceeding critical shall discharge into an energy dissipator to reduce velocity to less than critical.

3. The cross-section shall be triangular, parabolic, or trapezoidal. Cross-sections made of monolithic concrete may be retangular.

4. The minimum freeboard for lined waterways or outlets shall be 0.25 feet above design high water in areas where erosion-resistant vegetation cannot be grown adjacent to the paved side slopes. No freeboard is required if vegetation can be grown and maintained.

5. The steepest permissible side slopes, horizontal to vertical, shall be:

Nonreinforced concrete:	Maximum allowable slope
Hand packed, formed concrete	
Height of lining, 1.5 feet or less	Vertical
Hand packed, screened concrete or mortared in place flagstone	
Height of lining, less than 2 feet	1 to 1
Height of lining, more than 2 feet	2 to 1

Slip form concrete:	
Height of lining, less than 3 feet	1 to 1
Rock riprap	2 to 1

6. Minimum lining thickness shall be:

Concrete	4 inches (In most problem areas, minimum thickness shall be inches with welded wire fabric reinforcing.)
Rock riprap	Maximum stone size plus thickness of filter or bedding.
Flagstone	4 inches, including mortar bed.

7. Side inlets, drop structures, and energy dissipators shall meet the hydraulic and structural requirements for the site.

8. Filters or bedding shall be used to prevent piping. Drains shall be used to reduce uplift pressure and to collect water, as required. Filters, bedding, and drains shall be designed according to SCS standards. Weep holes may be used with drains if needed.

9. Concrete used for lining shall be proportioned so that it is plastic enough for thorough consolidation and still enough to stay in place on side slopes. A dense durable product shall be required. Specify a mix that can be certified as suitable to produce a minimum strength of at least 3,000 pounds/inch2. Cement used shall be Portland cement, Types I, II, or if required Types IV or V. Aggregate used shall have a maximum size of 1-1/2 inches.

10. Mortar used for mortared in place flagstone shall consist of a workable mix of cement, sand, and water with a water cement ratio of not more than 6 gallons of water per bag of cement.

11. Contraction joints in concrete linings, if required, shall be formed transversely to a depth of about one-third the thickness of the lining at a uniform spacing in the range of 10 to 15 feet. Provide for uniform support to the joint to prevent unequal settlement.

12. Stone used for riprap shall be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone shall be flat for ease of placement and have the strength to resist exposure and breaking.

13. Provisions must be made for timely maintenance to insure that lined waterways function properly.

14. Plans and specifications for constructing lined waterways or outlets shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purposes.

Construction Specifications - Permanent Lined Waterway or Outlet

1. The foundation area shall be cleared of trees, stumps, roots, sod, loose rock or other objectionable material.

2. The cross-section shall be excavated to the neat lines and grades as shown on the plans. Overexcavated areas shall be backfilled with moist soil compacted to the density of the surrounding material.

3. No abrupt deviations from design grade or horizontal alinement shall be permitted.

4. Concrete linings shall be placed to the thickness shown on the plans and shall be finished in a workmanlike manner. Provisions shall be made to protect freshly placed concrete and to insure proper curing.

5. Filter, bedding, and rock riprap shall be placed to line and grade and in the manner specified. Riprap shall be placed so that it does not reduce the design section more than 10 percent.

6. Construction operations shall be done in such a manner that erosion and air and water pollution are minimized, and held within reasonable and legal limits. The completed job shall be workmanlike and present a good appearance. All disturbed areas shall be vegetated or otherwise provided with a cover to protect the areas against soil erosion.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

13. PERMANENT RIPRAP STANDARD

Definition

A layer of loose rock or aggregate placed over an erodible soil surface.

Purpose

The purpose of riprap is to protect the soil surface from the erosive forces of water.

Scope

This standard applies to the design and placement of all nongrouted riprap where the slopes are 2:1 or flatter. For the design and placement of grouted riprap on slopes that are steeper than 2:1 see the local USDA, Soil Conservation office or other qualified engineers.

Conditions where this Practice Applies

This practice applies to soil-water interfaces where the soil conditions, water turbulence and velocity, expected vegetative cover and groundwater conditions are such that the soil may erode under the design flow conditions. Riprap may be used at such places as storm drain outlets, channel banks and/or bottoms, roadside ditches, drop structures, shorelines, and any other outlet.

Design Considerations

Design criteria for permanent riprap should include the following:

1. peak discharge from a 10-year frequency storm that the riprap shall be expected to carry,
2. erosive forces of flowing water over the riprap,
3. slope and placing of the riprap,
4. size and quality of the riprap,
5. placement and quality of the bedding,
6. maintenance requirements.

Unit Cost Guide

Riprap - typically $5.50-$9.00/cubic yard in the Fall of 1979 - dependent on size of riprap and distance from quarry.

Source and Reference

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specification

Design plans and specifications for riprap should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose.

Permanent Riprap Sample Specifications

Design Specifications

1. The minimum design discharge for channels and ditches shall be the peak discharge from a 10-year frequency rainfall event based on maximum watershed development during the life of the structure. The roughness coefficient, n, used for determining flow on the constructed riprap surface shall be as given by curve 1 in Appendix B.

   For design of riprap lined channels, refer to the National Cooperative Highway Research Program Report number 108, entitled "Tentative Design Procedure For Riprap Lined Channels". This is a procedure for determining a design stone size such that the stone is stable under the design flow conditions with a reasonable factor of safety. The design stone size used in this Standard and Specifications is the d50 or median stone diameter which is defined as the stone size such that 50 percent of the mixture, by weight, is larger than that size. The riprap design procedure is given in Appendix B.

   Erosive forces of flowing water are greater in bends than in straight channels. Riprap size for bends in the channel shall be computed according to the procedure in Appendix B. If the riprap size (d50) computed for bends is less than 10 percent greater than the riprap size (d50) for straight channels, then the riprap size for straight channels shall be considered to be adequate size, otherwise the larger riprap size shall be used in the bend. This allowance is made in order to minimize the number of riprap sizes required. No more than two riprap sizes should be used on any single contract in order to minimize construction problems caused by too many sizes. The riprap size to be used in a bend shall extend upstream from the point of curvature and downstream from the point of tangency a distance equal to five times the channel bottom width. (Length = 5b). This riprap size shall extend across the bottom and up both sides of the channel.

   For erosion of tidal shores see the U.S. Army Corps of Engineers "Shore Protection Manual".

2. The riprap shall be composed of a well-graded mixture down to the one-inch size particle such that 50% of the mixture by weight shall be larger than the d50 size as determined from the design procedure. A well-graded mixture as used herein is defined as a mixture composed primarily of the larger stone sizes but with a sufficient mixture of other sizes to fill the progressively smaller voids between the stones. The diameter of the largest stone size

in such a mixture shall be considered to be 1.5 times the d50 size. The riprap size as shown on the plans and specifications or for other construction purposes shall be the size of the largest stone in the mixture, i.e., 1.5 x d50. The minimum thickness of the riprap layer shall be 1.5 times the maximum stone diameter but not less than six inches. The riprap shall extend up the banks to a height equal to maximum depth of flow or to a point where vegetation can be established to adequately protect the channel.

In channels where there is no riprap or paving in the bottom, the toe of the bank riprap shall extend below the channel bottom a distance at least 1.5 times the maximum stone size but in no case less than one foot. The only exception to this would be in the event that there is a non-erodible hard rock bottom. The channel bank shall not be steeper than 2.0 horizontal to 1 vertical.

The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of damage by children shall be considered in selecting a riprap size, especially if there is nearby water into which the stones may be tossed.

3. Stone for riprap shall consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all other respects for the purpose intended. The specific gravity of the individual stones shall be at least 2.5.

   Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirements of this Standard and Specifications.

4. Riprap shall have a filter placed under it when either of the two following conditions exist:

   A. The riprap is not well graded down to the one-inch size particle.

   B. Riprap is placed on the side slopes of a channel and the soil is sand-size or finer with a plasticity index less than 10. This requirement applies to slopes having this soil in lenses or layers greater than 3 inches in thickness.

   A filter can be of two general forms. One is a single layer of plastic filter cloth manufactured for that express purpose. The plastic filter cloth shall be woven of polypropylene monofilament yarns and shall be equivalent to "Poly-Filter X" as manufactured by Carthage Mills, Inc., Cincinnati, Ohio. Another is a properly graded layer of sand, gravel, or stone.

The criteria for the design of an aggregate filter is as follows:

$$\frac{d15\ \text{Riprap}}{d85\ \text{Filter}} \leq 5 \qquad \frac{d15\ \text{Filter}}{d85\ \text{Base}} \leq 5$$

in which d15 and d85 is the size of base, filter or riprap material of which 15 and 85% respectively is finer. The base means the soil layer underneath the filter. The filter shall be graded down to sand-size particles. Riprap that is 12" and larger shall not be dumped directly onto the plastic filter cloth since it may tear or displace the filter cloth. Instead, a 4-inch minimum thickness blanket of gravel shall be placed over the filter cloth or the riprap shall be placed directly on the filter cloth by hand or by the bucket of the equipment. Side slopes shall be 2:1 or flatter in order for the gravel not to slide down the filter cloth before placing the riprap.

5. Soil sizes given herein are according to the Unified Soil Classification System as shown below.

Soil	Sieve Size
Gravel	Smaller than 3" and larger than #4 Sieve (Approx. 1/4")
Sand	Smaller than #4 seive and larger than #200 Sieve (0.074 mm)

Construction Specifications - Permanent Riprap

1. The subgrade for the riprap or filter shall be prepared to the required lines and grades. Any fill required in the subgrade shall be compacted to a density approximating that of the surrounding undisturbed material.

2. The rock or gravel shall conform to the specified grading limits when installed respectively in the riprap or filter.

3. Plastic filter cloth shall be protected from punching, cutting or tearing. Any damage other than an occasional small hole shall be repaired by placing another piece of cloth over the damaged part or by completely replacing the cloth. All overlaps whether for repairs or for joining two pieces of cloth shall be a minimum of one foot.

4. The stone for the filter and riprap may be placed by equipment. Both filter and riprap shall each be constructed to the full course thickness in one operation and in such a manner to avoid displacement of the underlying materials. The stone for filter and

riprap shall be delivered and placed in a manner that will insure that the filter and riprap shall be reasonably homogeneous with the smaller stones and spalls filling the voids between the larger stones. Riprap shall be placed in a manner to prevent damage to the filter blanket. Hand placing will be required to the extent necessary to prevent damage to the permanent works.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

14. PERMANENT STORM DRAIN PROTECTION STANDARD

Definition

Storm drain outlet protection is the providing of de-energizing devices and erosion resistant channel sections between storm drain outlets and stable existing downstream channels. The channel sections may be rock-lined, vegetated, paved with concrete or otherwise made erosion resistant.

Purpose

The purpose of outlet protection is to convert pipe flow to channel flow, and reduce the velocity of the water consistent with the channel lining in order to convey the flow of water to a stable existing downstream channel without causing erosion.

Scope

This standard applies to all permanent storm drain outlets.

Conditions where this Practice Applies

This practice applies to storm drain outlets, road culverts, paved channel outlets, etc. discharging into natural or constructed channels, which in turn discharge into existing streams or drainage systems. Analysis and appropriate treatment shall be done along the entire length of the flow path from the end of the conduit, channel or structure to the point of entry into an existing stream or publicly maintained drainage system.

Design Considerations

Design considerations should include the following:

1. plan view, profile and cross-section of each channel reach between the storm drain outlet and the existing publicly maintained system or natural stream channel. A channel reach is defined as a length of channel throughout which the hydraulic characteristics do not change. These include channel depth of flow, roughness, channel gradient, side slopes, bottom width, discharge rate and velocity;

2. maximum allowable water velocity through each channel reach;

3. type of storm drain outlet protection (aprons, lined waterways, riprap or vegetative protection);

4. compliance with all local and state regulations and requirements;

5. maintenance requirements.

Unit Cost Guide

Vegetated channels	- typically	\$0.50-\$ 1.00/square foot.
Riprap construction	- "	\$6.00-\$15.00/linear foot.
Concrete construction	- "	\$7.50-\$20.00/linear foot.

Variability in costs are due to size of outlet, topography and availability of materials. All costs are based on Fall of 1979.

Sources and References

This standard has been prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for installing storm drain outlet protection should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose. For alternative methods of design, consult the local USDA, Soil Conservation Service office or other qualified engineers.

Sample Permanent Storm Drain Outlet Protection Specifications

Design Specifications - Pipe Outlets

All pipe outlets shall have a structurally-lined apron or other suitable de-energizing device immediately downstream from the outlet where the water can change from pipe flow to channel flow. The structurally-lined apron shall meet the following criteria:

1. Bottom grade of 0.0%

2. Side slopes of 2:1 or flatter.

3. The top of the sidewall shall extend at least one foot above maximum tailwater but no lower than two-thirds of the vertical conduit dimension above the conduit invert.

4. Invert elevation at the end is equal to or lower than the lowest elevation on the cross-section immediately downstream from the end of the apron. (i.e., no overfall at the end of the apron).

5. Size of riprap and length of apron shall meet the criteria from Design of Outlet Protection in Appendix C, and riprap shall meet the Standard and Specifications for Riprap. Concrete paving may be substituted for the riprap. 50% of the stone size of the riprap mixture, by weight, shall be larger than the median stone diameter.

6. Where there is no well defined channel immediately downstream of the apron, the width of the end of the apron shall be as follows: (a) for tailwater elevation greater than or equal to the elevation of the center of the pipe, W = diameter + 0.4 La; (b) for tailwater elevation less than the elevation of the center of the pipe, W = diameter + La; where La is the length of apron determined from the curves in Appendix C.

   Where there is a well defined channel immediately downstream of the apron, the width of the end of the apron shall be equal to the width of the channel section immediately downstream from the apron.

7. There shall be no bends or curves in the horizontal alignment of the pipe and the apron unless the structure is designed to adequately handle the flow.

8. Tailwater shall be determined by computing depth of flow in the channel reach immediately downstream from the apron by the use of Manning's equation.

Design Specifications - Paved Channel Outlets

Paved channel sections shall meet the following criteria:

1. Velocity in the end of the paved section is no greater than the allowable velocity for the succeeding downstream section.

2. The downstream end of the invert of the paved section shall be no higher than the lowest point in the channel immediately downstream from the end of the paved section (i.e., no overfall at the end of the apron).

3. The end of a paved channel shall merge smoothly with the next downstream channel section and this transition shall be accomplished within the paved channel. The bottom width of the end of the paved channel shall be at least as wide as the bottom width of the downstream channel. The maximum side divergence of a transition shall be 1 in 3F, where the Froude number, F = V ; where V equals velocity in feet per second, d equals depth of flow in feet at the beginning of the transition, g is acceleration due to gravity (32.2 feet per second).

4. Bends or curves in the horizontal alignment of paved channels are not acceptable unless the Froude number, F, is 1.0 or less or the channel is specifically designed to contain the turbulent flow.

<u>Design Specifications</u> - Riprap or Vegetative Protection

Each channel reach having a natural, vegetated or riprap-paved bottom shall be checked for stability by calculating the flow velocity using Manning's equation and assuring that the channel will handle that velocity without eroding. These compuations will necessitate thorough field review and inspection.

<u>Design Specifications</u> - Channel Roughness

For the purpose of design the roughness coefficient, n, used in calculations shall be as follows:

Channel Lining	n value
Asphaltic Concrete - machine finished	0.018
hand finished	0.022
Concrete-Float finish	0.015
Unfinished	0.017
Shotcrete, unfinished	0.022
Natural channels not completely lined with vegetation	0.025
Gabion mattresses	0.028
Fabriform - Filter point (waffled surface)	0.025
Riprap	See Standard and Specifications for Riprap
Vegetation	See Standard and Specifications for Grassed Waterway

Design Specifications - Velocities

Maximum flow velocities at design capacity shall be as follows:

Channel Lining	Maximum Velocity, fps
Natural channels not completely lined with vegetation	
Sand and sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel and graded loam to gravel	5.0
Graded silt to cobbles	5.5
Shale, hardpan and coarse gravels	6.0
Riprap	See Standard and Specifications for Riprap
Vegetation	See Standard and Specifications for Grassed Waterway

Construction Specifications - Permanent Storm Drain Outlet Protection

1. For natural or vegetated channels, see Standard and Specifications for Grassed Waterway.

2. For riprap construction, see Standard and Specifications for Riprap.

3. Aprons at the end of pipe or lined channel outlets shall meet the following criteria:

   A. Bottom grade shall be 0.0%.

   B. Side slopes 2:1 or flatter.

   C. Sidewalls shall extend up as shown on the plans but not less than two-thirds the pipe diameter.

   D. There shall be no overfall from the end of the apron to the surface of the receiving channel. The area to be paved or riprapped shall be undercut so that the invert of the apron shall be at the same grade (flush) with the surface of the receiving channel. The apron shall have a cutoff or toe wall at the downstream end.

   E. Apron dimensions and riprap size or concrete thickness must be as shown on the plans.

   F. The width of the receiving end of the apron shall be equal to the bottom width of the receiving channel.

G. The placing of fill, either loose or compacted, in the receiving channel shall not be allowed.

H. No bends or curves in the horizontal alignment of the apron will be permitted.

4. Paved channel sections shall meet the following criteria:

A. Side slopes, dimensions, grades, etc. shall be as shown on the plans.

B. There shall be no overfall from the end of the paving to the surface of the receiving channel.

C. Riprap size or concrete thickness, joint details, etc. shall be as shown on the plans.

D. The end of paved sections shall be as wide as the receiving channel and the transition betwee n the two channels shall be smooth.

E. The placing of fill, either loose or compacted in the receiving channel shall not be allowed.

F. Bends or curves in the horizontal alignment of paved channels are not acceptble unless shown on the plans and radius of curvature must be the same as shown on the plans.

Source and Reference

This specification has been prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplification and improved clarity.

15. GENERAL LAND GRADING PRACTICES STANDARD FOR MINIMIZING EROSION

Definition

Reshaping of the existing topography in accordance with a plan as determined by engineering survey and layout.

Purpose

The purpose of the land grading standard is to provide for erosion control and vegetative establishment on those areas where the existing topography is to be reshaped by grading according to plan.

Scope

This standard shall be used for all land grading in urban and suburban areas that do not exceed any limits as given in the sample specifications.

Conditions where this Practice Applies

Land grading is done in any area where the existing topography does not suit development or construction for urban or suburban uses.

Design Consideration

Design and installation should be based on adequate engineering surveys and investigations.

Design grade and dimension limitations should be suitable for the particular site, conservation system, or land use. If other conservation practices are needed to accomplish the stated purpose, they should be included in the plans for improvement. Consideration should be given to erosion hazards when determining slope length and grade.

Unit Cost Guide

Variable - dependent on local topography and nature of earth being graded.

Source and Reference

This standard was prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Design Plans and Specifications

Design plans and specifications for land grading should be in keeping with this standard and shall describe the requirements for applying the practice to achieve the intended purpose.

Sample Permanent Land Grading Specifications to Minimize Erosion

Design Specifications

The grading plan shall be based upon the incorporation of buildng designs and street layout that fit and utilize existing topography and desirable natural surroundings to avoid extreme grade modifications. Information submitted will provide sufficient topographic surveys and soil investigations to determine limitations that must be imposed on a grading operation related to slope stability, effect on adjacent properties and drainage patterns, measures for drainage and water removal and vegetative treatment, etc.

The plan must also show existing and proposed contour of the area or areas to be graded. The plan shall also include practices or erosion control, slope stabilization, safe disposal of runoff water and drainage, such as waterways, lined ditches, reverse slope benches (include grade and cross-section). Grade stabilization structure, retaining walls, and surface and subsurface drains. The land shall also include scheduling and phasing of these practices. The following shall be incorporated into the plan:

1. Provisions shall be made to safely conduct surface runoff to storm drains, protected outlets or to stable water courses to insure that surface runoff will not damage slopes or other graded areas. (See Standard and Specifications for Grassed Waterway, Diversion, Grade Stabilization Structure).

2. Cut and fill slopes shall not be steeper than 2:1. Where the slope is to be mowed, the slope shall be no steeper than 3:1 (4:1 is preferred because of safety factors related to mowing steep slopes).

3. Reverse slope benches or diversions shall be provided whenever the vertical interval (height) of any 2:1 through 5:1 slope exceeds 15 feet. Benches shall be located so as to divide the slope face as equally as possible and shall convey the water to a stable outlet. Soils, seeps, rock outcrops, etc., shall also be taken into consideration when designing benches.

   A. Benches shall be wide enough to accommodate the construction equipment in use and provide for ease of maintenance.

   B. Benches shall be designed with a reverse slope of 5:1 or flatter to the toe of the upper slope and with a minimum of 1 foot in depth. Bench gradient to the outlet shall be between 1% and 2%.

   C. The surface flow across a bench shall not exceed a linear distance of 800 feet. (See Standard and Specifications for Diversion.)

4. Surface water shall be diverted from the face of all cut and/or fill slopes by the use of diversions, ditches and swales, or conveyed downslope by the use of a designed structure, except where:

A. The length of overland flow (in feet) to the crest of the slope shall not exceed the distance "A" given in the following diagram and example for any combination of side slopes and vertical intervals and;

B. The face of the slope is or shall be stabilized and the face of all graded slopes shall be protected from surface runoff until they are stabilized and;

C. The face of the slope shall not be subjected to any concentrated flows of surface water from natural drainageways, graded swales, downspouts, etc.

The maximum total horizontal overland-flow-plus-slope distance (B) shall not exceed 15 times the side slope (X) of the cut or fill slope. Maximum allowable overland flow* distance (in feet) to the top of the slope with no diversion of surface water will be determined by use of the formula $A=X(15-Y)$. Where:

A = Maximum overland flow distance in feet to slope crest.

B = Maximum horizontal distance in feet (shall not exceed 15X).

X = Side slope; Horizontal distance in feet to 1 foot vertical.

Y = Vertical interval; Height of cut/fill slope in feet measured vertically from bottom elevation of slope to slope crest.

*If maximum allowable overland flow is exceeded, surface water shall be diverted from the slope face and carried to a stable outlet, or conveyed downslope with a designed structure.

5. Serrated cut slopes shall be constructed so as to facilitate longlasting vegetative stabilization. These serrations shall be made in rippable rock with conventional equipment as the excavation is made. Each step or serrate shall be constructed on the contour and will have steps cut at nominal two-foot intervals with nominal three-foot horizontal shelves. These steps will vary depending on the slope ratio of the cut slope. The normal slope line is 1-1/2:1. These steps will weather and act to hold moisture, lime, fertilizer and seed, and to produce much quicker and longer lived vegetative cover and slope stabilization. Overland flow shall be diverted from the top of all serrated cut slopes and carried to a suitable outlet.

6. Subsurface drainage shall be provided where necessary to intercept seepage that would otherwise adversely affect slope stability or create excessively wet site conditions that would hinder or prohibit vegetative establishment (See Standard and Specifications for Subsurface Drain).

7. Slopes shall not be created so close to property lines as to endanger adjoining properties without adequately protecting such properties against erosion, slippage, settlement, subsidence or other related damages.

8. Material for earth fills shall be obtained from designated areas. Except for approved landfills, the fill material shall be free of brush, rubbish, rocks, logs, stumps, building debris, and other objectionable material that would interfere with or prevent construction of satisfactory fills. It should be free of stones over 2 inches in diameter where compacted by hand or mechanical tampers, or over 6 inches in diameter where compacted by rollers or other equipment.

9. Stockpiles, borrow areas and spoil areas shall be shown on the plans and shall be subject to the provisions of this Standard and Specification.

10. All disturbed areas shall be stabilized structurally or vegetatively in compliance with the Standard and Specifications for the appropriate practices.

Construction Specifications - Permanent Land Grading

1. All graded or disturbed areas including slopes shall be protected during clearing and construction in accordance with the aproved sediment control plan until they are permanently stabilized.

2. All sediment control practices and measures shall be constructed, applied and maintained in accordance with the approved sediment control plan and the Standards and Specifications for the appropriate soil erosion preventive practices.

3. If topsoil is required for the establishment of vegetation it shall be stockpiled in the amount necessary to complete finished grading of all exposed areas.

4. Areas to be filled shall be cleared, grubbed and stripped of topsoil to remove trees, vegetation, roots or other objectionable material.

5. Areas which are to be topsoiled shall be scarified to a minimum depth of three inches prior to placement of topsoil.

6. All fills shall be compacted as required to reduce erosion, slippage, settlement, subsidence or other related problems. Fill intended to support buildings, structures and conduits, etc., shall be compacted in accordance with local requirements or codes.

7. All fill shall be placed and compacted in layers not to exceed 8 inches per lift.

8. Except for approved landfills, fill material shall be free of brush, rubbish, rocks, logs, stumps, building debris and other objectionable materials that would interfere with or prevent construction of satisfactory fills.

9. Soft, mucky or highly compressible materials shall not be incorporated into fills.

10. All benches shall be kept free of sediment during all phases of development.

11. Seeps or springs encountered during construction shall be handled in accordance with the Standard and Specifications for Subsurface Drain or other approved methods.

12. All graded areas shall be permanently stabilized immediately following finished grading.

13. Stockpiles, borrow areas, and spoil areas shall be shown on the plans and shall be subject to the provisions of this Standard and Specifications.

Sources and References

This specification was prepared by the USDA, Soil Conservation Service. The language of this specification has been modified by ABAG for simplication and improved clarity.

16. PERMANENT SUBSURFACE DRAIN STANDARD

Definition

A conduit, such as tile, pipe, or tubing, installed beneath the ground to collect and/or convey drainage water.

Purpose

To: improve the soil environment for vegetative growth by regulating the water table and groundwater flow; intercept and prevent water movement into a wet area; relieve artesian pressure; remove surface runoff; facilitate leaching of saline and alkaline soils; serve as an outlet for other subsurface drains.

Scope

This standard applies to the design and installation of conduits placed beneath the surface of the ground to provide drainage and reduce erosion.

Conditions where this Practice Applies

In areas having a high water table where benefits of lowering or controlling groundwater or surface runoff justify installing such a system.

In areas that are suitable for the intended use after installation of such required drainage, the soil shall have enough depth and permeability to permit installation of an effective and economically feasible system. The drainability and treatment of saline and alkaline soils is to be considered where this is a problem.

The outlet should be adequate for the quantity and quality of effluent to be disposed. Consideration shall be given to possible damages above or below the point of discharge that might involve legal actions under state or local laws.

Design Consideration

Design should include specifications for the following:

1. Required capacity of drains.
2. Size of subsurface drain.
3. Depth and spacing of drains.
4. Minimum velocity and grade.
5. Materials to be used in construction of subsurface drains.
6. Maximum loading rates.
7. Envelopes and envelope material.
8. Auxiliary structure and subsurface drain protection.

Unit Cost Guide

Variable - dependent on size and design.

Source and Reference

This standard was prepared by the USDA, Soil Conservation Service. The language of this standard has been modified by ABAG for simplification and improved clarity.

Plans and Specifications

Plans and specifications for installing subsurface drains should be in keeping with this standard and should describe the requirements for applying the practice to achieve its intended purpose. For alternative design methods and more information, consult the local USDA, Soil Conservation Service office or a qualified engineer.

Permanent Subsurface Drain Specifications

Design Specifications

1. The required capacity shall be determined by one or more of the following:

   A. Where subsurface drainage is to be uniform over an area through a systematic pattern of drains, a drainage coefficient of 1 inch to be removed in 24 hours shall be used. (See drain charts in Appendix D).

   B. Where subsurface drainage is to be by a random system, a minimum inflow rate of 1.5 cfs per 1,000 feet of line shall be used to determine required capacity.

   For interceptor subsurface drains on sloping land, increase the inflow rate as follows:

Land Slopes	Increase Inflow Rate By
2 - 5 percent	10 percent
5 - 12 percent	20 percent
over 12 percent	30 percent

   C. Additional design capacity must be provided if surface water is allowed to enter the system.

2. The size of subsurface drains shall be determined from the Drain Charts found in Appendix D. All subsurface drains shall have a nominal diameter which equals or exceeds 4 inches.

3. The minimum depth of cover of subsurface drains shall be 24 inches where possible. The minimum depth of cover may be reduced to a minimum of 12 inches where it is not possible to attain the 24 inch depth and where the drain is not subject to damage by equipment loading or frost action. Roots from some types of vegetation can plug drains as the drains get closer to the surface.

   The spacing of drain laterals will be dependent on the permeability of the soil, the depth of installation of the drains and degree of drainage required. Generally, drains installed 36 inches deep and spaced 50 feet center-to-center will be adequate. For more specific information, consult the local USDA, Soil Conservation Service office.

4. The minimum grade for subsurface drains shall be 0.10 percent. Where surface water enters the system, a velocity of not less than 2 feet per second shall be used to establish the minimum grades. Provisions shall be made for preventing debris or sediment from entering the system by means of filters or collection and periodic removal of sediment from installed traps.

5. Acceptable subsurface drain materials include perforated, continuous closed joint conduits of polyethylene plastic, concrete, corrugated metal, asbestos-cement, bituminized fiber and poly-vinyl chloride.

   The conduit shall meet strength and durability requirements of the site.

6. These allowable loads on subsurface drain conduits shall be based on the trench and bedding conditions specified for the job. A factor of safety of not less than 1.5 shall be used in computing the maximum allowable depth of cover for a particular type of conduit.

7. Envelopes shall be used around subsurface drains for proper bedding of the conduit. Not less than three inches of envelope material shall be used for sand-gravel envelopes. Where necessary to improve the characteristics of flow of groundwater into the conduit, more envelope material may be required.

   Envelope material shall be placed to the height of the uppermost seepage strata. Behind bulkhead and retaining walls, it shall go to within 12 inches of the top of the structure. This does not cover the design of filter materials where needed.

   Materials used for envelopes shall not contain materials which will cause an accumulation of sediment in the conduit or render the envelope unsuitable for bedding of the conduit. Envelope materials shall consist of sand-gravel material, all of which shall pass a 1.5 inch sieve, 90 to 100% shall pass a .75 inch sieve, and not more than 10% shall pass a No. 60 sieve.

   The conduit shall be placed and bedded in a sand-gravel envelope. A minimum of 3 inches depth of envelope material shall be placed on the bottom of a conventional trench. The conduit shall be placed on this and the trench completely filled with envelope material to minimum depth of 3 inches above the conduit.

   Soft or yielding soils under the drain shall be stabilized where required and lines protected from settlement by adding gravel or other suitable material to the trench, by placing the conduit on plank or other rigid support, or by using long section of perforated or watertight pipe with adequate strength to insure satisfactory subsurface drain performance.

8. The outlet shall be protected against erosion and undermining of the conduit, against damaging periods of submergence and aganst entry of rodents or other animals into the subsurface drain. (See Drawing for Animal Guard in the Appendix D.)

   A continuous 10 foot section of corrugated metal, cast iron, or steel pipe without perforations shall be used at the outlet end of the line and shall outlet above the normal elevation of low flow in the outlet ditch or above mean high tide in tidal areas. No

envelope material shall be used around the 10 foot section of pipe. Two-thirds of the pipe shall be buried in the ditch bank and the cantilevered section shall extend to a point above the toe of the ditch side slope or the side slope shall be protected from erosion.

Conduits under roadways and embankments shall be watertight and designed to withstand the expected loads.

Where surface water is to be admitted to subsurface drains, inlets shall be designed to exclude debris and prevent sediment from entering the conduit. Lines flowing under pressure shall be designed to withstand the resulting pressures and velocity of flow. (See Surface Water Inlet Drawing in Apendix D.) Surface waterways shall be used where feasible.

The upper end of each subsurface drain line shall be capped with a tight fitting cap of the same material as the conduit or other durable material unless connected to a structure.

Construction Specifications - Permanent Subsurface Drain

1. Deformed, warped, or otherwise damaged pipe or tubing shall not be used.

2. All subsurface drains shall be laid to a uniform line and covered with envelope material. The pipe or tubing shall be laid with the perforations down and oriented symmetrically about the vertical center line. Connections will be made with manufactured functions comparable in strength with the specific pipe or tubing unless other wise specified. The method of placement and bedding shall be as specified on the drawing.

3. Envelope material shall be a sand-gravel material all of which shall pass the 1.5 inch sieve, 90 to 100% shall pass the .75 inch sieve, and not more than 10% shall pass the No. 60 sieve.

4. The upper end of each subsurface drain line shall be capped with a tight fitting cap of the same material as the conduit or other durable material unless connected to a structure.

5. A continuous 10 foot section of corrugated metal, cast or steel pipe without perforations shall be used at the outlet end of the line. No envelope material shall be used around the 10 foot section of pipe. An animal guard shall be installed on the outlet end of the pipe.

6. Earth backfill material shall be placed in the trench in such a manner that displacement of the drain will not occur.

Source and Reference

This standard specification has been prepared by the USDA, Soil Conservation Service.

III. PUBLIC WORKS PRACTICES

A. BASIC PRINCIPLES

Currently public works practices are structured to satisfy aesthetic, private property protection and public health objectives. The Best Management Practices presented here are designed to provide water quality benefits without regard to other benefits, uses, or objectives of those public works practices.

These standards for public works practices were based on mathematical modelling and statistical analyses of local and national data (e.g., data on pollutant accumulation rates on streets and pollutant removal efficiencies of street sweeping and catch basin cleaning practices). Practices which showed statistically significant water quality benefits were identified. The standards were based on those practices shown to be highly effective at reducing potential water quality pollutants at little or no additional cost.

A number of municipal management practices were examined for which the existing information did not indicate that improved water quality benefits could be derived by specifying Best Management Practices. In this category are street surface condition, street cleaning equipment selection, and litter control.

B. LOCAL LAWS AND REGULATIONS

1. Model Parking Ordinance to Increase Street Sweeper Effectiveness

Where the analyses set forth in "Standards for Parking Restrictions During Street Sweeper Operations" (see III.C.2) indicate parking restrictions would be cost-effective and where the local jurisdiction decides such restrictions are compatible with other policy concerns, e.g. traffic flow, litter control, etc., the following model ordinance may be used by that jurisdiction as a guide to enacting a self-sufficient ordinance or to modifying an existing one.

1. MODEL PARKING ORDINANCE TO INCREASE STREET SWEEPER EFFECTIVENESS

100.00 Title. This Chapter shall be known as the "(City) Parking Restrictions for Street Sweeping" and may be so cited.

100.01 Purpose. The purpose of this Chapter is to improve the effectiveness of street sweeping operations in removing street solids through the implementation of parking restrictions.

100.02 Definitions. Whenever any words or phrases used in this Chapter are not defined in this section, but are defined in the Vehicle Code of the State of California and amendments thereto, the Vehicle Code definitions shall apply.

The following words and phrases when used in this ordinance shall, for the purpose of this ordinance, have the meanings respectively ascribed to them in this section.

(a) Curb Occupancy. The percentage of the curb length occupied by parked vehicles.

(b) Hours(s). Whenever certain hours are named herein, they shall mean standard time or daylight saving time as may be in current use in this city.

(c) Official Traffic Control Devices. All signs and markings placed or created by authority of the Director of ( ) (hereinafter "Director") under this Chapter.

(d) Park. To stand or leave standing a vehicle, whether occupied or not, otherwise than temporarily for the purpose of and while actually engaged in the loading or unloading of passengers or materials.

(e) Police Officer. Every officer of the Police Department of this city or any other person authorized to direct or regulate traffic or to make arrests for violations of traffic regulations.

(f) Stand. When prohibited means any stopping of a vehicle, and leaving same unattended, except when necessary to avoid conflict with other traffic or in compliance with the directions of a police officer or official traffic control device.

(g) Street. Street is a way or place of whatever nature, publicly maintained and open to the use of the public for purposes of vehicular travel. Except a street is not a highway and a highway is not a street.

201.01 Application of Regulations. The provisions of this Chapter prohibiting the standing or parking of a vehicle shall apply during those hours herein specified, except when it is necessary to stop a vehicle to avoid conflict with other traffic or in compliance with the directions of a police officer or official traffic control device.

201.02 No Standing and No Parking Areas. The Director shall designate pursuant to §301.01 areas wherein neither parking nor standing shall be allowed during specified hours.

No operator of any vehicle shall stand, park or leave standing said vehicle in area designated by the Director pursuant to this section and §301.01, and for which area the Director has established appropriate signs or markings pursuant to §201.03.

201.03 Director to Establish and Maintain No Standing Zones and No Parking Areas. The Director shall establish and maintain, by appropriate signs or markings, all no standing and no parking areas as defined and described in this Chapter and shall give notice by appropriate signs or markings that vehicles parked or left standing in violation of such prohibitions are subject to removal from the street.

201.04 Violations. When signs or markings described in §201.03 are in place, it shall be unlawful and shall constitute an infraction for any operator of a vehicle to stand or park said vehicle in violation of said sign or marking.

201.05 Penalties. Every person convicted of a violation of this Chapter shall be deemed guilty of an infraction and shall be punished by a fine not to exceed \$( ).

201.06 When Vehicles May Be Removed From Streets. Any police officer may remove or cause to be removed any vehicle parked or left standing upon a street when such parking or standing is prohibited by this Chapter and signs or markings giving notice of such prohibition and of such removal are in place. The operator(s) or owner(s) of record of such vehicles shall pay the reasonable cost of removing the vehicle.

301.01 Designation of No Parking and No Standing Areas. The Director shall designate each street named by the (City Council of) as a no standing and no parking zone during the hours said street may be serviced by a mechanical street sweeper. Such hours for each street shall be set forth in a schedule of street sweeper operations submitted to the Director and may be amended from time to time.

1. STANDARD FOR SCHEDULING STREET CLEANING TO MINIMIZE SOLIDS WASHOFF

Definition

Seasonal street cleaning scheduling to reduce amount of solids washing off the street.

Purpose

Protection of beneficial uses of surface waters receiving stormwater washoff from urban street surfaces.

Scope

Curbed streets in urban areas that are cleaned by street cleaners and drained by storm sewers discharging directly or indirectly to surface waters without intervening treatment are affected by this standard.

Conditions Where This Practice Applies

All streets within the scope of this practice should be cleaned according to this standard. Streets where more frequent cleaning is warranted by other considerations such as aesthetics or safety may be so cleaned.

Design Criteria

The most cost effective street cleaning schedule for any budget level or amount of solids prevented from washing off should be determined using the Street Solids Washoff Model given in the design methodology. Values for the model inputs should be used that reflect, as accurately as feasible, conditions in the areas being scheduled.

L: number of design areas (maximum of 4)

LU: number of land uses (maximum of 3, same in all design areas, i.e., residential, commercial, industrial)

LOC: name of each design area

USE: name of each land use

SL: average street solids load before cleaning for each location and land use

SLS and SLM: For each location and land use, these are the coefficients in the equation that describes the daily solids accumulation rate as a function of the solids load on the street at the beginning of the day. The equation is:

street solids load at end of day = (street solids load at beginning of day x SLS) + SLM.

SE: Street cleaning efficiency for each location and land use. SE is computed as:

$$SE = 1 - \left(\frac{\text{street solids load after cleaning}}{\text{street solids load before cleaning}}\right)$$

SC: Street cleaning cost for each location in dollars per curb mile per pass.

CM: Number of curb miles for each location/land use.

RT: Threshold rainfall in inches per day below which intensity no solids washoff is assumed to occur. This value is typically 0.2 inches/day except in special circumstances (Pitt, 1979).

R: Daily rainfall record in inches per day for four years considered typical for the area being modeled. Fewer years of record may be used with minor adjustments to the computer program.

RA: Rainfall adjustment factor for each location. This factor adjuts the rainfall record to account for minor differences between precipitation at the rain gauge providing the record and at the area being scheduled. RA is computed as:

$$RA = \left(\frac{\text{rainfall at area being scheduled}}{\text{rainfall at rain gauge providing record}}\right)$$

The input format for the Street Solids Washoff Model is explained in the comment statements at the beginning of the program listing given in the design methodology, Appendix E. The flow chart for the model is given in Appendix E.

Benefits

By scheduling street cleaning operations according to water quality objectives, program effectiveness can often be improved by a factor of two compared to typical programs. That is, for the same expenditure, twice the amount of solids can be prevented from washing off the streets, or the same amount of solids can be prevented from washing off the streets for half the cost. These savings are very approximate and depend upon the structure of the existing street cleaning schedule.

Cost Guide

The unit costs for the sample computation based on San Jose data are given in Appendix E. The unit costs may vary widely depending upon the cleaner performance and solids accumulation rate for a given jurisdiction. Many street cleaning schedules would be revised so that the street cleaning effort is redistributed rather than expanded in light of this standard. Such schedule changes should not incur added costs.

Sources and References

1. J.B. Gilbert and Assoc., August 1978. Water Quality Control Investigation: Urban Runoff, Construction Activities, Agricultural Practices, Appendix 2.1-1. Prepared for Southern California Association of Governments.

2. Russell, Peter. 1980. "Regional Evaluation of Street Sweeping as a Water Quality Control Measure." Water Quality Technical Memorandum No. 38. Association of Bay Area Governments.

3. Pitt, Robert, 1979. "Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Prctices," prepared for the U.S. Environmental Protection Agency. Grant No. S-804432.

2. STANDARD FOR PARKING RESTRICTIONS DURING STREET SWEEPING OPERATIONS

Definition

Identification of periods of street sweeping activity, during which no curb-side parking or standing is permitted, with effective enforcement of this restriction.

Purpose

Identify streets where institution of parking and standing restrictions would permit economic removal of an additional amount of solids from street surface; and provide street cleaning vehicle access to curb lanes on such streets and where no other considerations preclude such restrictions.

Scope

Curbed streets in urban areas that are cleaned by street cleaning vehicles and drained by storm sewers would be affected by this standard.

Conditions Where This Practice Applies

The analytic methodology described here should be used by each jurisdiction to identify streets where parking and standing restrictions are cost effective. The important factors in the analysis are the effective sweep efficiencies with and without parking restrictions, and the unit cost of solids removal with and without the parking restriction program.

For streets serviced by street cleaning vehicles, the following values must be estimated as accurately as is feasible:

1. f: the annual sweeping frequency--the number of passes the street cleaning vehicle makes on each curb on the street each year.

2. CC: the current total cost of sweeping one curb mile once (there are two curb miles per street mile).

3. IC: the annual total implementation cost, per curb mile, of posting and maintaining signs and markings which indicate parking or standing restrictions and the time during which such restrictions are in effect.

4. EC: the comprehensive enforcement costs, per curb mile, for each time the sweeper services the street.

5. The curb occupancy typically occurring during the hours when the sweeper services the street.

6. The curb occupancy typically occurring on the street in the long term (24 hours per day).

7. CR: the current total street solids removed (as percent of the total solids load on the street) with no parking controls and with the sweeper moving around cars as necessry. If local data are not readily available, Table III.C.2.1 should be consulted to obtain CR corresponding to existing curb occupancy.

8. RR: the total street solids removed (as percent of the total solids load on the street) with parking controls and with sweeper moving next to the curb. If local data are not readily available, Table III.C.2.1 should be consulted to obtain RR corresponding to existing curb occupancy.

TABLE III.C.2.1
INFLUENCE OF PARKED CARS ON STREET SWEEPING EFFECTIVENESS

Normal Percentage of Curb Occupied by Parked Cars	Percentage of All Solids Removed with Parking Restrictions and Sweeper Operated in Curb Lane, RR	Percentage of All Solids Removed with No Parking Restrictions and with Sweeper Moving Around Parked Cars as Necessary, CR	Improvement in Percentage of All Solids Removed with Parking Restrictions
0	50	50	0
10	49	42	7
20	48	36	12
30	47	31	16
40	46	26	20
50	45	21	24
60	43	19	24
70	39	16	23
80	35	18	17
90	28	23	5
100	0	50	-50
80% for 24 hrs.	30	19	11
90% for 24 hrs.	0	43	-43
100% for 24 hrs.	0	50	-50

Using the variable values appropriate for each street, the following formula should be used to calculate the ratio of the unit cost of removing additional street solids as a result of imposing parking restrictions to the unit cost of removing street solids without such restrictions:

$$\frac{\left(\frac{(IC/f) + EC}{RR - CR}\right)}{\left(\frac{CC}{RR}\right)} = \frac{\text{unit cost of increased removal due to restrictions}}{\text{current unit cost}} = \text{unit removal cost ratio.}$$

The definitions of variables assigned above apply in this equation. For streets where the value of the equation is less than one (1), additional solids can be swept at less cost per pound removed with parking restrictions than without such restrictions. This analysis ignores program revenues generated through citations of parking restriction violators. These revenues would further favor the imposition of parking restrictions.

When the results of the analysis indicate parking restrictions would be cost efficient (when the equation evaluates to greater than zero(0) but less than one(1)), the jurisdiction should then determine whether such restrictions are compatible with other policies and planning goals. Some pertinent considerations are litter control, traffic flow, availability of alternate parking sites, and the development or availability of mass transit in the affected areas.

Design Considerations

Where appropriate, an enforceable parking ordinance should be adopted. The Model Parking Ordinance of Section III.B.1 is an example of an effective ordinance which may be incorporated into a pre-existing general ordinance or stand alone.

Benefits

The benefits of parking restrictions are shown, using typical sweep efficiencies, on Table III.C.2.2. The precise unit removal cost ratio obtainable by a jurisdiction may vary somewhat from the values on Table III.C.2.2, thus local data should be used when available. Note that with high curb occupancy, negative benefits accrue when parking restrictions are implemented.

Cost Guide

The following cost figures are approximate and may range substantially among jurisdictions:

1. posting and maintaining restricted parking signs: $182 per curb mile per year (J.B. Gilbert and Assoc., 1978)

2. enforcement of parking restrictions: $0.23 per curb mile per sweep (J.B. Gilbert and Assoc., 1978)

3. revenue from parking citations: $12.25 per curb mile per sweep assuming:

   a. 245 parking spaces per curb mile
   b. route is patrolled and citations issued every other time the sweeper passes

c. a $10.00 citation is collected from 1% of the spaces each time the area is patrolled.

Sources and References

1. Association of Bay Area Governments, April, 1980. Model Parking Ordinance to Increase Street Sweeper Effectiveness. (Section III.B.1)

2. J.B. Gilbert and Assoc., August 1978. Water Quality Control Investigation: Urban Runoff, Construction Activities, Agricultural Practices, Appendix 2.1-1. Prepared for Southern California Association of Governments.

3. Pitt, Robert, 1979. Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices. Preparedfor U.S. Environmental Protection Agency. Grant No. S-804432.

4. Bursztynsky, T.A., 1980, "Evaluation of Using Parking Restrictions to Increase Street Sweeping Effectiveness," Water Quality Technical Memorandum No. 45, Association of Bay Area Governments.

TABLE III.C.2.2
Unit Removal Cost Ratio for Enforced Parking Restrictions

percentage of curb length occupied	current sweeping costs = $7/curb mile			current sweeping costs = $12/curb mile		
	sweeping frequency			sweeping frequency		
	daily	weekly	monthly	daily	weekly	monthly
10	0.80	3.20	13.20	0.47	1.87	7.70
20	0.40	1.60	6.60	0.23	0.93	3.85
30	0.26	1.03	4.26	0.15	0.60	2.49
40	0.17	0.69	2.86	0.10	0.40	1.67
50	0.12	0.47	1.92	0.07	0.27	1.12
60	0.11	0.42	1.74	0.06	0.25	1.02
70	0.09	0.37	1.53	0.05	0.22	0.89
80	0.14	0.56	2.33	0.08	0.33	1.36
90	0.61	2.45	10.12	0.36	1.43	5.90
100	*	*	*	*	*	*
80% for 24 hrs.	0.23	0.92	3.80	0.13	0.54	2.22
90% for 24 hrs.	*	*	*	*	*	*
100% for 24 hrs.	*	*	*	*	*	*

Note: The table entries are unit removal cost ratios using the values on Table III.C.2.1 with the equation and the cost assumptions given herein.

* Negative ratio due to lowered solids removal with parking restrictions.

3. STANDARD FOR STREET SURFACE MATERIAL SELECTION

Definition

Selection of the paving material used to surface permanent streets and roads.

Purpose

To minimize surface runoff pollution from street surfaces by using pavement types showing significantly lower water contaminant accumulation rates.

Scope

Permanent streets whose stormwater runoff enters surface waters either directly or indirectly without intervening treatment.

Conditions Where Practice Applies

When asphalt and concrete are being considered as street surface paving materials and no overriding selection considerations pertain. This best management practice does not apply where plant and algal growth in the receiving water body is known to be nitrogen limited.

Design Considerations

Concrete shall be used as the street surface paving material rather than asphalt.

Benefits

The ratios of the mass water pollutant accumulation rates for contaminants found to vary significantly between street surface types are shown on Table III.C.3.1.

TABLE III.C.3.1

Parameter	Asphalt surface accumulation rate ÷ concrete surface accumulation rate
Total Solids	2.69
BOD	0.80
COD	1.00
Ortho-PO	1.52
NO	0.19
Org - N	1.12
Cr	4.07
Fe	3.90
Pb	4.67
Sr	1.20
Zn	3.81

The tabulated parameter accumulation rate ratios are for equivalent land uses.

Sources and References

1. Amy, G., R. Pitt, R. Singh, W.L. Bradford, and M.B. LaGraff. 1974. Water Quality Managemetn Planning for Urban Runoff. U.S. Environmental Protection Agency. EPA 440/9-75-004.

2. Russell, Peter. 1980. "The Influence of Street Surface Type and Condition on Street Solids Loading Rate and Comosition." Water Quality Technical Memorandum No. 40. Association of Bay Area Governments.

4. STANDARD FOR CATCH BASIN CLEANING AS A SURFACE RUNOFF CONTROL MEASURE

Definition

Removal of the solid and liquid contents of catch basins serving storm sewers, for disposal other than to surface waters without treatment.

Purpose

To prevent pollutants accumulated in catch basins from reaching surface waters.

Scope

Catch basins in urban areas that discharge through storm sewers to surface waters. Catch basins on combined sewer systems and on storm sewer systems that incorporate treatment processes for pollutant removal are not covered by this standard. This standard does not apply to storm sewer inlets without sumps designed to trap solids and prevent them from entering the collection system.

Conditions Where Practice Applies

All catch basins within the scope of this standard.

Design Considerations

An analysis of existing information on catch basins suggests that surface runoff pollutants can be kept from reaching surface waters at a lower unit cost by catch basin cleaning than by street cleaning (Dietrich and Davis, 1980). The study recommended, however, that a more refined analysis be undertaken before a decision can be made. On the basis of the preliminary analysis, catch basin cleaning should be conducted.

Each time a catch basin is cleaned, as much of the solid and liquid contents should be removed as is feasible. At the same time, care should be taken to prevent solid and liquid material from entering the storm sewer in the cleaning process. Adequate information is not available to recommend a specific catch basin cleaning method at present. Each jurisdiction should use the method that best suits the resources available to them, except that flushing of the catch basin contents into the storm sewer is unacceptable.

The preliminary catch basin analysis indicates that no increase in the percentage removed of the total amount of material entering the basin is obtained using cleaning frequencies greater than twice annually. Catch basins should be cleaned twice per year and should be at least one-half full before cleaning.

Benefits

Pollutants removed in catch basin cleaning and consequently prevented from entering surface waters occur in both the liquid and solid fractions of the catch basin contents. The estimated average 5-day biochemical oxygen demand in the liquid fraction of catch basin contents is 60 grams (Dietrich and Davis, 1980). Most of this load would be washed into the storm sewer by a moderate storm. The typical solids content of a catch basin is between 2,500 and 5,000 lbs. (Dietrich and Davis, 1980). The void created upon maintenance removal of the solids will catch more solids during the next storm thus preventing them from reachng the surface waters.

Cost Guide

Catch basin cleaning costs average about $20 per basin. Aproximately 125 to 250 lbs. of solids per cleaning dollar are removed (Dietrich and Davis, 1980). These costs do not include expenses incurred in disposing of the removed materials.

Sources and References

Dietrich, William F. and John A. Davis, 1980. "Catch Basin and Storm Sewer Cleaning as Surface Runoff Control Measures." Water Quality Technical Memorandum No. 49. Prepared for Association of Bay Area Governments.

5. STANDARD FOR STORM SEWER INLET CLEANING

Definition

Cleaning of storm sewer inlet structures that have no sumps specifically designed to trap solids.

Purpose

To reduce surface runoff pollution from urban areas by removing accumulated solids from inlets to storm sewer systems.

Scope

Inlets on urban storm sewers draining directly or indirectly to surface water without intervening treatment.

Conditions where this practice applies

All inlets in urban areas comparable to Oakland, should be cleaned according to this standard. Catchbasins, which have a reservoir or sump to collect solids or liquids, are not included in this standard. Due to lack of information, inlets in suburban or semi-rural areas also are not included in this standard.

Design Considerations

A program for cleaning inlets should include the following considerations:

1. accumulation rate of solids;
2. design of inlet;
3. rainfall season;
4. method of cleaning, i.e. manual or vacuum.

Benefits

A sampling of 20 inlets in Oakland, California showed solids accumulation ranging from 13 to 163 pounds per inlet, with an average of 57 pounds (Detrick and Davis, 1980). The weighted averages of the solids constituents included 16 percent chemical oxygen demand (COD), 0.03 percent nitrogen, 0.1 percent phosphorus and 0.1 percent lead. Inlets appear to be less effective than catch basins in retaining pollutants due to a lack of a reservoir or sump in the inlet.

Cost Guide

A survey of inlet cleaning costs was conducted in the Fall of 1979 (Dietrich and Davis, 1980). Based upon the reported data, the most per inlet for each cleaning ranged from $4.00 to $17.00. There was no correlation between cleaning method and reported cost. Based upon on average inlet content of 57 pounds of solid, inlet cleaning could cost between $.07 and $.30 per pound of solids removed.

Sources and References

Dietrich, William F. and John A. Davis, 1980, "Catch Basin and Storm Sewer Cleaning as Surface Runoff Control Measures." Water Quality Technical Memorandum No. 49, Association of Bay Area Governments.

6. STANDARD FOR LEAF REMOVAL

Definition

Collection of leaves and other waste products of urban vegetation for disposal.

Purpose

To prevent pollution of surface waters from nutrients released and/or oxygen consumed in the natural decomposition of leaves and related vegetable matter. While the natural degradation of these materials on land is beneficial for soil enrichment, when occurring in surface waters, decomposition can impair beneficial uses.

Scope

Urban areas where fallen leaves and related dead vegetation refuse may enter storm sewers.

Conditions Where Practice Applies

Where fallen leaves and related non-growing vegetable matter would otherwise enter surface waters draining urban areas. Target materials are those falling on lawns, driveways, or other landscaped areas, that would be swept onto the street for disposal and those falling directly onto streets and sidewalks.

Design Considerations

Leaves and related materials falling directly onto streets should be collected using customary street sweeping methods. Although collection of other leaves covered by this standard is recommended, adequate information to assess which method is best from an environmental and economic perspective is not available. Typically leaves are collected by either manual or mechanical methods. The manual method entails workers loading piled leaves onto trucks. Often bagging of the leaves is required to facilitate handling. Mechanical methods include: 1) using a street sweeper--with or without a trash-screen mounted on the front to push leaves into piles for loading, 2) using front end loaders to collect leaf piles and load them into trucks, and 3) using a vacuum truck.

Combining leaf collection with the regular garbage collection program, except possibly during the heavy leaf-fall season, may be most appropriate for many communities. Additional effort will probably be necessary in autumn.

Benefits

Preventing fallen leaves and related dead vegetable matter from entering surface waters removes a substantial nutrient and oxygen consumption load from the receiving water bodies. Although decay rates vary with

vegetation type, complete decomposition can be expected to release nearly all of the nitrogen and phosphorus present to the water body. The nitrogen content of leaves is usually 0.5 to 2.5 percent of dry weight. Phosphorus ranges from 0.07 to 0.25 percent of dry weight. The amount of dissolved oxygen removed from the water during complete decomposition of leaves is 50 to 75 percent of the dry weight of the leaves.

Costs

Typical unit costs for leaf removal are \$0.06/lb for leaves collected by vacuum truck and \$0.04/lb for pickup of bagged leaves in residential areas (Dietrich and Davis, 1980).

Sources and References

Dietrich, William F. and John A. Davis, 1980. "Leaf Removal as a Surface Runoff Control Measure." Prepared for Association of Bay Area Governments, San Francisco Bay Area Water Quality Planning Program, Water Quality Technical Memorandum No. 57.

APPENDICES

APPENDIX A

Sample Waterway and Diversion Design

The following material is provided to assist in the design of grassed waterways and diversions:

1. Graph of the Product of Velocity and Hydraulic Radius versus Mannings "n" for different degrees of vegetal retardance.

2. Table giving classification of vegetal cover based on degree of flow retardance by the vegetation.

3. Parabolic Waterway Design Tables for various grades and velocities for retardance "D", and top width and depth for retardance "C".

4. Trapezoidal Channel Design Tables for various grades, velocities and depths for retardance "C".

The use of these tables and graphs can best be shown by example problems, which are as follows:

Problem 1

Determine the non-erosive velocity and dimensions for stability and capacity for a waterway with parabolic cross-section.

Given:	Runoff	Q = 55 cfs
	Grade	= 5.1 percent
	Vegetative cover	Kentucky bluegrass
	Condition of vegetation	
	Good stand-mowed (3"-4")	= "D" curve retardance
	Good stand-headed (6"-12")	= "C" curve retardance
	Permissible velocity	= 4 ft./sec. (from Pg. 36.02)

Solution: Horizontally opposite 55 cfs on the Parabolic Waterway Design Table for Grade = 5.0 percent (slope table that is nearest 5.1%) and the columns headed V = 4.0 ft./sec., find T = 33 feet and D = 0.8 feet.

Therefore, a waterway with parabolic cross section, a top width of 33 feet, and a depth of 0.8 feet will carry 55 cfs at a maximum velocity of 4 feet per second when the vegetative lining is short (3" to 4" in height). This complies with the requirement for non-erosive velocity when vegetation is short ("D" retardance) and for capacity when vegetation is tall ("C" retardance).

Reference: USDA, Soil Conservation Service, National Engineering Handbook, Section 5, Hydraulics

This sample design procedure is provided by the USDA, Soil Conservation Service.

Problem 2

Determine the non-erosive velocity and dimensions for a waterway with trapezoidal cross-section.

Given:	Runoff	Q = 55 cfs
	Grade	= 2 percent
	Side slopes	= 2:1
	Vegetative cover	Kentucky bluegrass
	Condition of vegetation	
	Good stand-headed (6"-12")	= "C" curve retardance
	Permissible velocity	= 5 ft./sec. (from Pg. 36.02)

Solution: Horizontally opposite 55 cfs on the Trapezoidal Channel Design Table for Grade = 2.0 percent, read across to the column for bottom width = 6 feet and read the D = 1.3 feet and V = 4.9 ft./sec.

Therefore, a waterway with trapezoidal cross-section, 2:1 side slope, bottom width of 6 feet, and a depth of 1.3 feet will carry 55 cfs at a maximum velocity of 4.9 feet per second for "C" curve retardance.

Problem 3

Determine the safe velocity and dimensions for a waterway with trapezoidal cross-section that does not fit the Trapezoidal Channel Design Tables.

Given:	Runoff	Q = 55 cfs
	Grade	= 3 percent
	Side slope	= 3:1
	Vegetative cover	Kentucky bluegrass
	Condition of vegetation	
	Good stand-mowed (3"-4") = "D" curve retardance	
	Good stand-headed (6"-12") = "C" curve retardance	
	Permissible velocity = 5 ft./sec. (from Pg. 36.02)	

Solution: The solution is a trial and error process. The first step is to design for stability when the vegetation is short ("D" retardance) and the second step is to design for capacity when the vegetation is tall ("C" retardance).

Step 1 - Stability

$Q = 55$ cfs.

$V_{max} = 5$ ft./sec.

$$A = \frac{Q}{V_{max}} = \frac{55}{5} = 11 \text{ sq.ft.}$$

Try Bottom Width = 12 feet

$A = bd + zd^2$

$11 = 12d + 3d^2$

Note: Solve for d by use of the quadratic equation.

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$3d^2 + 12d - 11 = 0$$

$$d = \frac{-12 \pm \sqrt{12^2 - 4(3)(-11)}}{2(3)}$$

$$d = \frac{-12 + 16.61}{6} = \frac{4.61}{6}$$

$$d = 0.77 \text{ feet}$$

Hydraulic Radius

$$r = \frac{\text{area}}{\text{wetted perimeter}} = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}}$$

$$r = \frac{12(0.77) + 3\ (0.77^2)}{12 + 2(0.77)\sqrt{3^2 + 1}}$$

$$r = \frac{9.24 + 1.78}{12 + 4.87}$$

$$r = \frac{11.02}{16.87} = 0.65$$

$$Vr = 5(0.65) = 3.25$$

From graph, page A-36.15 for Vr=3.25 and "D" retardance, read n = 0.04

$$V = \frac{1.486}{n}\ r^{2/3}\ s^{1/2}$$

$$= \frac{1.486}{0.04}\ (0.65^{2/3})(.03^{1/2}) = 4.83 \text{ ft./sec.}$$

Okay, but less than V_{max} - try slightly smaller channel.

Try bottom width = 10 feet

$A = bd + zd^2$

$11 = 10d + 3d^2$

$$d = \frac{-b \pm\sqrt{b^2 - 4ac}}{2a} = 0.87$$

$$r = \frac{bd + zd^2}{b + 2d\sqrt{z^2 + 1}} = 0.71$$

$Vr = 3.55$

$n = 0.040$ from page A-36.15

$$V = \frac{1.486}{n} r^{2/3} \quad s^{1/2} = 5.15$$ which is greater than V_{max}

Therefore, select design bottom width = 12 feet

Velocity = 4.83 feet/sec. for "D" retardance

$d = 0.8'$

Step 2 - Capacity check using "C" curve retardance. Determine additional depth needed to offset the increase retardance and decreased velocity.

Try d = 0.9 feet

$A = bd + zd^2 = (12)(0.9) + 3(.9^2) = 13.23$

$$r = \frac{A}{P} = \frac{13.23}{b+2d\sqrt{z^2+1}} = \frac{13.23}{12+2(.9)\sqrt{3^2 +1}} = 0.75$$

Assume V = 4.4 ft./sec.

$Vr = (4.4)(0.75) = 3.30$

From graph, page A-36.15 for Vr = 3.30 and "C" retardance, read n = 0.046.

$$V = \frac{1.486}{0.046} (0.75^{2/3})(.03^{1/2}) = 4.62 \text{ ft./sec.}$$

which is greater than assumed value

Assume V = 4.6 ft./sec.

Vr = (4.6)(0.75) = 3.45

From graph, n = 0.046

$$V = \frac{1.486}{.046} (0.75^{2/3})(.03^{1/2}) = 4.62 \text{ ft./sec.}$$

which is close enough

Therefore, dimensions and velocities are as follows:

Bottom width = 12 feet

Side slopes = 3:1

For "D" retardance - V = 4.83 ft./sec.

d = 0.8 feet

For "C" retardance - V = 4.62 ft./sec.

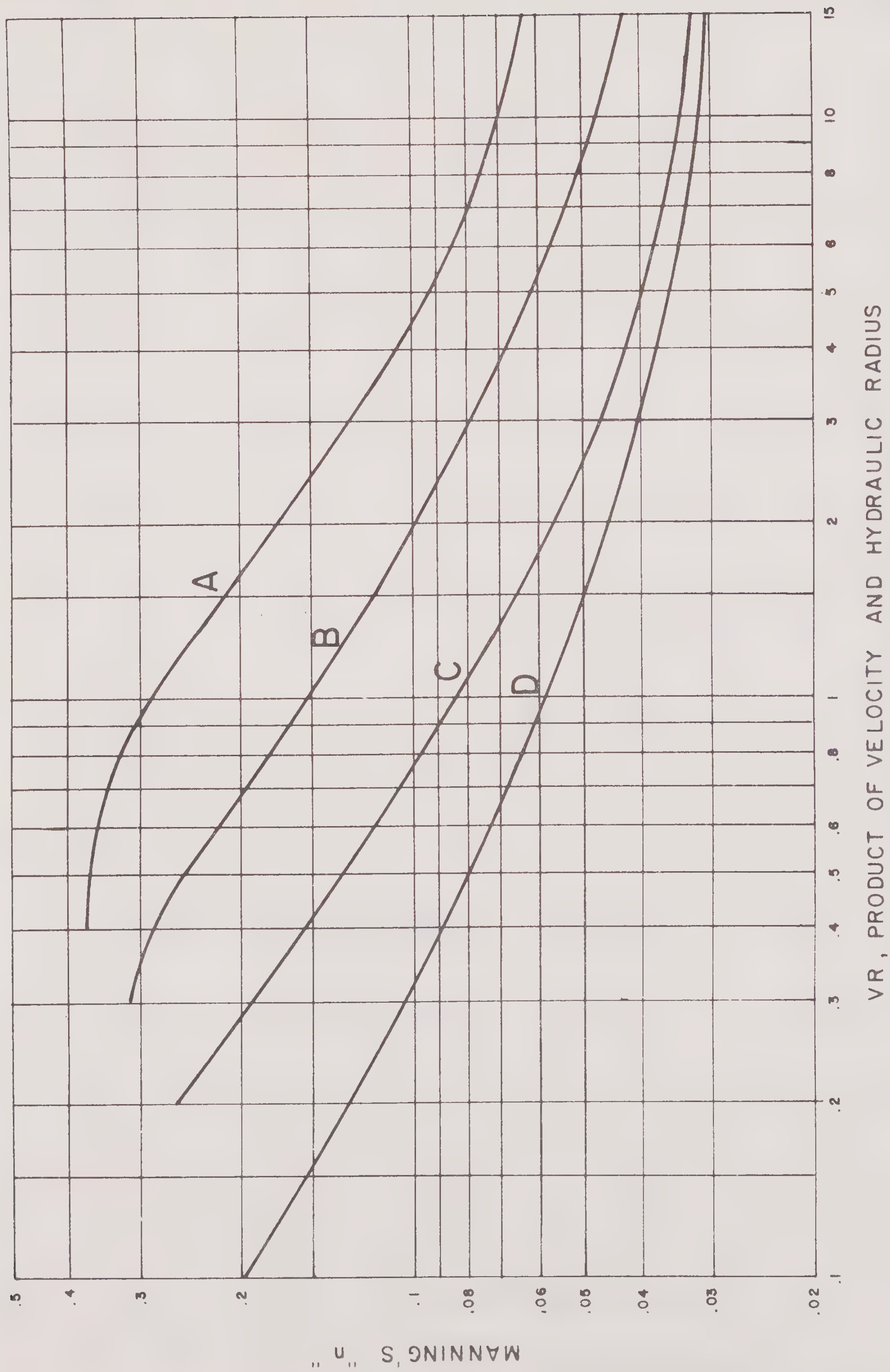
d = 0.9 feet + freeboard.

GRASSED WATERWAY AND DIVERSION

DESIGN TABLE (15)

Retardance	Cover	Stand	Condition and Height
A	Reed canarygrass	Excellent	Tall (Average 36")
	Kentucky 31 tall fescue	Excellent	Tall (Average 36")
B	Tufcote, Midland and Coastal bermudagrass	Good	Tall (Average 12")
	Reed canarygrass	Good	Mowed (Avg. 12 to 15")
	Kentucky 31 tall fescue	Good	Unmowed (Avg. 18")
	Red fescue	Good	Unmowed (Avg. 16")
	Kentucky bluegrass	Good	Unmowed (Avg. 16")
	Redtop	Good	Average 22"
C	Kentucky bluegrass	Good	Headed (6 to 12")
	Red fescue	Good	Headed (6 to 12")
	Tufcote, Midland and Coastal bermudagrass	Good	Mowed (Average 6")
	Redtop	Good	Headed (15 to 20")
D	Tufcote, Midland and Coastal bermudagrass	Good	Mowed (2 1/2")
	Red fescue	Good	Mowed (2 1/2")
	Kentucky bluegrass	Good	Mowed (2 - 5")

Classification of vegetal cover in waterways and diversions based on degree of flow retardance.



Manning's "n" related to velocity, hydraulic radius, and vegetal retardance. (15)

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 0.25 Percent(14)

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15																		
20																		
25	10	2.4																
30	11	2.3																
35	13	2.3																
40	15	2.3	10	2.7														
45	17	2.2	12	2.6														
50	19	2.2	13	2.6														
55	20	2.2	14	2.6														
60	22	2.2	15	2.5														
65	24	2.2	17	2.5														
70	26	2.2	18	2.5	13	3.1												
75	28	2.2	19	2.5	13	3.0												
80	29	2.2	20	2.5	14	3.0												
90	33	2.2	23	2.5	16	3.0												
100	38	2.2	25	2.5	18	3.0												
110	40	2.2	28	2.5	19	2.9												
120	44	2.2	30	2.5	21	2.9	15	3.6										
130	48	2.2	33	2.5	23	2.9	16	3.6										
140	51	2.2	35	2.5	25	2.9	18	3.5										
150	55	2.2	37	2.5	26	2.9	19	3.5										
160	58	2.2	40	2.5	28	2.9	20	3.5										
170	62	2.2	42	2.5	30	2.9	21	3.5	17	4.0								
180	66	2.2	45	2.5	31	2.9	22	3.5	18	4.0								

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 0.50 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	9	1.6																
20	11	1.6																
25	14	1.6	9	1.9														
30	17	1.6	11	1.9	8	2.2												
35	20	1.6	12	1.9	9	2.1												
40	22	1.6	14	1.8	11	2.1												
45	25	1.5	16	1.8	12	2.0												
50	28	1.5	18	1.8	13	2.0	10	2.4										
55	31	1.5	19	1.8	15	2.0	11	2.4										
60	33	1.5	21	1.8	16	2.0	11	2.4										
65	36	1.5	23	1.8	17	2.0	12	2.4										
70	39	1.5	24	1.8	18	2.0	13	2.3										
75	42	1.5	26	1.8	20	2.0	14	2.3	11	2.7								
80	44	1.5	28	1.8	21	2.0	15	2.3	12	2.7								
90	50	1.5	31	1.8	24	2.0	17	2.3	13	2.7								
100	55	1.5	35	1.8	26	2.0	19	2.3	15	2.6	12	3.0						
110	61	1.5	38	1.8	29	2.0	21	2.3	16	2.6	13	3.0						
120	66	1.5	42	1.8	31	2.0	22	2.3	18	2.6	14	2.9						
130	72	1.5	45	1.8	34	2.0	24	2.3	19	2.6	15	2.9						
140	77	1.5	48	1.8	36	2.0	26	2.3	20	2.6	16	2.9						
150	83	1.5	52	1.8	39	2.0	28	2.3	22	2.6	18	2.9	14	3.3				
160	88	1.5	55	1.8	41	2.0	30	2.3	23	2.6	19	2.9	15	3.3				
170	93	1.5	59	1.8	44	2.0	32	2.3	25	2.6	20	2.9	16	3.3				
180	99	1.5	62	1.8	47	2.0	33	2.3	26	2.6	21	2.9	17	3.3				

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 0.75 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	12	1.3	7	1.6														
20	16	1.3	9	1.5														
25	19	1.3	11	1.5	8	1.7												
30	23	1.3	13	1.5	10	1.7	8	1.9										
35	27	1.3	15	1.5	11	1.7	9	1.9										
40	31	1.3	18	1.5	13	1.7	10	1.9										
45	35	1.3	20	1.5	14	1.7	11	1.8										
50	38	1.3	22	1.5	16	1.6	13	1.8	9	2.2								
55	42	1.3	24	1.5	18	1.6	14	1.8	10	2.1								
60	46	1.3	26	1.5	19	1.6	15	1.8	11	2.1								
65	50	1.3	28	1.5	21	1.6	16	1.8	12	2.1	10	2.4						
70	53	1.3	30	1.5	22	1.6	17	1.8	13	2.1	11	2.4						
75	57	1.3	33	1.5	24	1.6	19	1.8	14	2.1	11.	2.3						
80	61	1.3	35	1.5	25	1.6	20	1.8	15	2.1	12	2.3						
90	68	1.3	39	1.5	28	1.6	22	1.8	16	2.1	13	2.3	11	2.6				
100	76	1.3	43	1.5	32	1.6	25	1.8	18	2.1	15	2.3	12	2.6				
110	83	1.3	48	1.5	35	1.6	27	1.8	20	2.0	16	2.3	13	2.6				
120	91	1.3	52	1.5	38	1.6	30	1.8	22	2.1	18	2.3	15	2.5	12	2.9		
130	98	1.3	56	1.5	41	1.6	32	1.8	23	2.1	19	2.2	16	2.5	13	2.8		
140	106	1.3	60	1.5	44	1.6	34	1.8	25	2.0	21	2.3	17	2.5	14	2.8		
150	113	1.3	65	1.5	47	1.6	37	1.8	27	2.0	22	2.2	18	2.5	15	2.8		
160	121	1.3	69	1.5	50	1.6	39	1.8	29	2.0	24	2.2	19	2.5	16	2.8	13	3.1
170	128	1.3	73	1.5	53	1.6	42	1.8	30	2.0	25	2.2	20	2.5	17	2.8	14	3.1
180	135	1.3	77	1.5	56	1.6	44	1.8	32	2.0	27	2.2	22	2.5	18	2.8	15	3.1

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 1.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	13	1.1	8	1.3														
20	18	1.1	11	1.3	8	1.5												
25	22	1.1	14	1.3	9	1.5	8	1.6										
30	27	1.1	17	1.3	11	1.5	9	1.6										
35	31	1.1	19	1.3	13	1.5	11	1.6	8	1.8								
40	35	1.1	22	1.3	15	1.4	12	1.6	9	1.8								
45	40	1.1	25	1.3	17	1.5	13	1.6	10	1.8								
50	44	1.1	28	1.3	19	1.4	15	1.6	11	1.8	9	2.0						
55	48	1.1	30	1.3	20	1.4	16	1.5	12	1.8	10	2.0						
60	53	1.1	33	1.3	22	1.4	18	1.5	14	1.7	10	2.0						
65	57	1.1	36	1.3	24	1.4	19	1.5	15	1.7	11	2.0	9	2.2				
70	61	1.1	38	1.3	26	1.4	21	1.5	16	1.7	12	2.0	10	2.2				
75	66	1.1	41	1.3	28	1.4	22	1.5	17	1.7	13	2.0	11	2.2				
80	70	1.1	44	1.3	29	1.4	24	1.5	18	1.7	14	2.0	11	2.2				
90	79	1.1	49	1.3	33	1.4	27	1.5	20	1.7	15	1.9	13	2.2	11	2.4		
100	87	1.1	55	1.3	37	1.4	29	1.5	22	1.7	17	1.9	14	2.2	12	2.4		
110	96	1.1	60	1.3	40	1.4	32	1.5	24	1.7	19	1.9	15	2.1	13	2.4	11	2.6
120	104	1.1	65	1.3	44	1.4	35	1.5	27	1.7	20	1.9	17	2.1	14	2.4	12	2.6
130	113	1.1	71	1.3	47	1.4	38	1.5	29	1.7	22	1.9	18	2.1	15	2.4	13	2.6
140	121	1.1	76	1.3	51	1.4	41	1.5	31	1.7	24	1.9	20	2.1	16	2.3	14	2.6
150	130	1.1	81	1.3	55	1.4	44	1.5	33	1.7	25	1.9	21	2.1	17	2.4	15	2.6
160	138	1.1	87	1.3	58	1.4	47	1.5	35	1.7	27	1.9	22	2.1	19	2.3	16	2.5
170	147	1.1	92	1.3	62	1.4	50	1.5	38	1.7	29	1.9	24	2.1	20	2.3	17	2.5
180	155	1.1	97	1.3	65	1.4	53	1.5	40	1.7	30	1.9	25	2.1	21	2.3	18	2.5

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 1.25 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	15	1.0	10	1.2	7	1.4												
20	20	1.0	13	1.1	9	1.3	7	1.5										
25	25	1.0	16	1.1	11	1.3	8	1.5	7	1.6								
30	31	1.0	19	1.1	13	1.3	10	1.4	8	1.6								
35	36	1.0	23	1.1	15	1.3	11	1.4	9	1.6	7	1.8						
40	41	1.0	26	1.1	17	1.3	13	1.4	11	1.6	8	1.8						
45	46	1.0	29	1.1	19	1.3	14	1.4	12	1.5	9	1.7						
50	50	1.0	32	1.1	21	1.3	16	1.4	13	1.5	10	1.7	8	2.0				
55	55	1.0	35	1.1	23	1.3	18	1.4	14	1.5	11	1.7	9	1.9				
60	60	1.0	38	1.1	26	1.3	19	1.4	16	1.5	12	1.7	10	1.9				
65	65	1.0	41	1.1	28	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.2		
70	70	1.0	45	1.1	30	1.3	22	1.4	18	1.5	14	1.7	11	1.9	9	2.2		
75	75	1.0	48	1.1	32	1.3	24	1.4	19	1.5	15	1.7	12	1.9	10	2.1		
80	80	1.0	51	1.1	34	1.3	25	1.4	21	1.5	16	1.7	13	1.9	11	2.1	9	2.3
90	90	1.0	57	1.1	38	1.3	29	1.4	23	1.5	18	1.7	15	1.9	12	2.1	10	2.3
100	100	1.0	63	1.1	42	1.3	32	1.4	26	1.5	20	1.7	16	1.9	13	2.1	11	2.3
110	109	1.0	70	1.1	46	1.3	35	1.4	28	1.5	22	1.7	18	1.9	14	2.1	12	2.2
120	119	1.0	76	1.1	51	1.3	38	1.4	31	1.5	24	1.7	19	1.8	16	2.1	14	2.2
130	129	1.0	82	1.1	55	1.3	41	1.4	33	1.5	26	1.7	21	1.8	17	2.1	15	2.2
140	139	1.0	88	1.1	59	1.3	44	1.4	36	1.5	28	1.7	23	1.8	18	2.1	16	2.2
150	148	1.0	94	1.1	63	1.3	47	1.4	38	1.5	30	1.7	24	1.8	19	2.0	17	2.2
160	158	1.0	101	1.1	67	1.3	50	1.4	41	1.5	32	1.7	26	1.8	21	2.1	18	2.2
170	168	1.0	107	1.1	71	1.3	54	1.4	43	1.5	34	1.7	27	1.8	22	2.1	19	2.2
180	177	1.0	113	1.1	75	1.3	57	1.4	46	1.5	36	1.7	29	1.8	23	2.1	20	2.2

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 1.50 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	17	0.9	11	1.1	8	1.2												
20	23	0.9	15	1.0	10	1.2	7	1.4	6	1.5								
25	28	0.9	19	1.0	12	1.2	9	1.4	7	1.5								
30	34	0.9	22	1.0	15	1.2	10	1.3	8	1.5	7	1.6						
35	40	0.9	26	1.0	17	1.1	12	1.3	10	1.4	8	1.6						
40	45	0.9	30	1.0	20	1.2	14	1.3	11	1.4	9	1.6	7	1.8				
45	51	0.9	33	1.0	22	1.1	15	1.3	12	1.4	10	1.5	8	1.8				
50	56	0.9	37	1.0	25	1.1	17	1.3	14	1.4	11	1.5	9	1.8				
55	62	0.9	41	1.0	27	1.1	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9		
60	67	0.9	44	1.0	30	1.1	20	1.3	16	1.4	14	1.5	11	1.7	9	1.9		
65	73	0.9	48	1.0	32	1.1	22	1.3	18	1.4	15	1.5	11	1.7	10	1.9		
70	78	0.9	51	1.0	34	1.1	24	1.3	19	1.4	16	1.5	12	1.7	10	1.9	9	2.1
75	83	0.9	55	1.0	37	1.1	25	1.3	21	1.4	17	1.5	13	1.7	11	1.9	9	2.1
80	89	0.9	59	1.0	39	1.1	27	1.3	22	1.4	18	1.5	14	1.7	12	1.9	10	2.1
90	100	0.9	66	1.0	44	1.1	30	1.3	25	1.4	20	1.5	16	1.7	13	1.9	11	2.0
100	111	0.9	73	1.0	49	1.1	33	1.3	27	1.4	22	1.5	17	1.7	15	1.9	12	2.0
110	121	0.9	80	1.0	54	1.1	37	1.3	30	1.4	25	1.5	19	1.7	16	1.8	14	2.0
120	132	0.9	87	1.0	58	1.1	40	1.3	33	1.4	27	1.5	21	1.7	18	1.9	15	2.0
130	143	0.9	95	1.0	63	1.1	43	1.3	35	1.4	29	1.5	22	1.7	19	1.8	16	2.0
140	154	0.9	102	1.0	68	1.1	47	1.3	38	1.4	31	1.5	24	1.7	20	1.8	17	2.0
150	164	0.9	109	1.0	73	1.1	50	1.3	41	1.4	33	1.5	26	1.7	22	1.8	18	2.0
160	175	0.9	116	1.0	78	1.1	53	1.3	43	1.4	36	1.5	27	1.7	23	1.8	20	2.0
170	186	0.9	123	1.0	82	1.1	57	1.3	46	1.4	38	1.5	29	1.7	25	1.8	21	2.0
180	196	0.9	130	1.0	87	1.1	60	1.3	49	1.4	40	1.5	31	1.7	26	1.8	22	2.0

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

Grade 1.75 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 4.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	19	0.9	12	1.0	9	1.1	6	1.3										
20	25	0.9	16	1.0	11	1.1	8	1.3	7	1.3								
25	31	0.9	20	1.0	14	1.1	10	1.2	8	1.3	7	1.5						
30	37	0.9	24	1.0	17	1.1	12	1.2	10	1.3	8	1.4						
35	43	0.9	28	1.0	20	1.1	13	1.2	11	1.3	9	1.4	7	1.6				
40	49	0.9	32	1.0	22	1.1	15	1.2	13	1.3	10	1.4	8	1.6				
45	55	0.9	36	1.0	25	1.1	17	1.2	14	1.3	12	1.4	9	1.6	8	1.7		
50	61	0.9	40	1.0	28	1.1	19	1.2	16	1.3	13	1.4	10	1.5	8	1.7		
55	67	0.9	44	1.0	31	1.1	21	1.2	17	1.3	14	1.4	11	1.5	9	1.7	8	1.9
60	73	0.9	48	1.0	33	1.1	23	1.2	19	1.3	15	1.4	12	1.5	10	1.7	8	1.9
65	78	0.9	52	1.0	36	1.1	25	1.2	21	1.3	17	1.4	13	1.5	11	1.7	9	1.9
70	84	0.9	56	1.0	39	1.1	27	1.2	22	1.3	18	1.4	14	1.5	12	1.7	10	1.9
75	90	0.9	59	1.0	42	1.1	29	1.2	24	1.3	19	1.4	15	1.5	12	1.7	10	1.9
80	96	0.9	63	1.0	44	1.1	30	1.2	25	1.3	20	1.4	16	1.5	13	1.7	11	1.9
90	108	0.9	71	1.0	50	1.1	34	1.2	28	1.3	23	1.4	18	1.5	15	1.7	12	1.9
100	120	0.9	79	1.0	55	1.1	38	1.2	31	1.3	25	1.4	20	1.5	16	1.7	13	1.9
110	131	0.9	87	1.0	61	1.1	42	1.2	34	1.3	28	1.4	22	1.5	18	1.7	15	1.8
120	143	0.9	94	1.0	66	1.1	45	1.2	38	1.3	30	1.4	24	1.5	20	1.7	16	1.8
130	155	0.9	102	1.0	71	1.1	49	1.2	41	1.3	33	1.4	26	1.5	21	1.7	17	1.8
140	166	0.9	110	1.0	77	1.1	53	1.2	44	1.3	35	1.4	28	1.5	23	1.6	19	1.8
150	178	0.9	117	1.0	82	1.1	56	1.2	47	1.3	38	1.4	30	1.5	24	1.6	20	1.8
160	189	0.9	125	1.0	88	1.1	60	1.2	50	1.3	40	1.4	31	1.5	26	1.6	21	1.8
170	201	0.9	132	1.0	93	1.1	64	1.2	53	1.3	43	1.4	33	1.5	28	1.6	23	1.8
180	212	0.9	140	1.0	98	1.1	67	1.2	56	1.3	45	1.4	35	1.5	29	1.6	24	1.8

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 2.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	21	0.8	13	0.9	9	1.0	7	1.2										
20	28	0.8	17	0.9	12	1.0	9	1.1	7	1.3	5	1.4						
25	35	0.8	21	0.9	15	1.0	11	1.1	8	1.3	7	1.4						
30	41	0.8	26	0.9	18	1.0	13	1.1	10	1.2	8	1.3	7	1.5				
35	48	0.8	30	0.9	22	1.0	15	1.1	11	1.2	9	1.3	8	1.5				
40	55	0.8	34	0.9	25	1.0	18	1.1	13	1.2	11	1.3	9	1.5	7	1.7		
45	62	0.8	38	0.9	28	1.0	20	1.1	14	1.2	12	1.3	10	1.4	8	1.6		
50	68	0.8	42	0.9	31	1.0	22	1.1	16	1.2	13	1.3	11	1.4	9	1.6	8	1.7
55	75	0.8	46	0.9	34	1.0	24	1.1	17	1.2	14	1.3	12	1.4	10	1.6	8	1.7
60	82	0.8	51	0.9	37	1.0	26	1.1	19	1.2	16	1.3	13	1.4	11	1.6	9	1.7
65	88	0.8	55	0.9	40	1.0	28	1.1	21	1.2	17	1.3	14	1.4	11	1.6	10	1.7
70	95	0.8	59	0.9	43	1.0	30	1.1	22	1.2	18	1.3	15	1.4	12	1.6	10	1.7
75	101	0.8	63	0.9	46	1.0	32	1.1	24	1.2	20	1.3	16	1.4	13	1.6	11	1.7
80	108	0.8	67	0.9	48	1.0	35	1.1	25	1.2	21	1.3	17	1.4	14	1.6	12	1.7
90	121	0.8	75	0.9	54	1.0	39	1.1	28	1.2	23	1.3	19	1.4	16	1.6	13	1.7
100	134	0.8	83	0.9	60	1.0	43	1.1	31	1.2	26	1.3	21	1.4	17	1.6	15	1.7
110	147	0.8	92	0.9	66	1.0	47	1.1	34	1.2	28	1.3	23	1.4	19	1.5	16	1.7
120	160	0.8	100	0.9	72	1.0	52	1.1	38	1.2	31	1.3	26	1.4	21	1.5	18	1.7
130	173	0.8	108	0.9	78	1.0	56	1.1	41	1.2	34	1.3	28	1.4	23	1.5	19	1.7
140	186	0.8	116	0.9	84	1.0	60	1.1	44	1.2	36	1.3	30	1.4	24	1.5	21	1.7
150	199	0.8	124	0.9	90	1.0	64	1.1	47	1.2	39	1.3	32	1.4	26	1.5	22	1.7
160	212	0.8	132	0.9	96	1.0	69	1.1	50	1.2	41	1.3	34	1.4	28	1.5	23	1.7
170	225	0.8	140	0.9	102	1.0	73	1.1	53	1.2	44	1.3	36	1.4	29	1.5	25	1.7
180	238	0.8	148	0.9	108	1.0	77	1.1	56	1.2	46	1.3	38	1.4	31	1.5	26	1.7

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 3.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	24	0.7	16	0.8	11	0.8	9	0.9	7	1.0	5	1.2						
20	31	0.7	22	0.8	15	0.8	12	0.9	9	1.0	7	1.1	6	1.2				
25	39	0.7	27	0.8	19	0.8	15	0.9	11	1.0	8	1.1	7	1.2	6	1.3		
30	47	0.7	32	0.8	23	0.8	17	0.9	13	1.0	10	1.1	9	1.2	7	1.2	6	1.4
35	55	0.7	38	0.8	26	0.8	20	0.9	15	1.0	11	1.1	10	1.1	8	1.2	7	1.4
40	62	0.7	43	0.8	30	0.8	23	0.9	17	1.0	13	1.1	12	1.1	9	1.2	8	1.4
45	70	0.7	48	0.8	34	0.8	26	0.9	19	1.0	15	1.1	13	1.1	11	1.2	9	1.3
50	77	0.7	54	0.8	38	0.8	29	0.9	21	1.0	16	1.1	14	1.1	12	1.2	9	1.3
55	85	0.7	59	0.8	41	0.8	32	0.9	23	1.0	18	1.1	16	1.1	13	1.2	10	1.4
60	93	0.7	64	0.8	45	0.8	35	0.9	26	1.0	19	1.1	17	1.1	14	1.2	11	1.3
65	100	0.7	70	0.8	49	0.8	37	0.9	28	1.0	21	1.1	19	1.1	15	1.2	12	1.3
70	107	0.7	74	0.8	52	0.8	40	0.9	30	1.0	22	1.1	20	1.1	16	1.2	13	1.3
75	115	0.7	79	0.8	56	0.8	43	0.9	32	1.0	24	1.1	21	1.1	18	1.2	14	1.3
80	122	0.7	85	0.8	59	0.8	46	0.9	34	1.0	26	1.1	23	1.1	19	1.2	15	1.3
90	137	0.7	95	0.8	67	0.8	51	0.9	38	1.0	29	1.1	26	1.1	21	1.2	17	1.3
100	152	0.7	105	0.8	74	0.8	57	0.9	42	1.0	32	1.1	28	1.1	23	1.2	19	1.3
110	167	0.7	116	0.8	81	0.8	63	0.9	46	1.0	35	1.1	31	1.1	26	1.2	21	1.3
120	181	0.7	126	0.8	89	0.8	68	0.9	51	1.0	38	1.1	34	1.1	28	1.2	22	1.3
130	196	0.7	136	0.8	96	0.8	74	0.9	55	1.0	41	1.1	37	1.1	30	1.2	24	1.3
140	211	0.7	146	0.8	103	0.8	79	0.9	59	1.0	44	1.1	39	1.1	32	1.2	26	1.3
150	225	0.7	156	0.8	110	0.8	85	0.9	63	1.0	47	1.1	42	1.1	35	1.2	28	1.3
160	239	0.7	166	0.8	117	0.8	90	0.9	67	1.0	50	1.1	45	1.1	37	1.2	30	1.3
170	254	0.7	176	0.8	124	0.8	96	0.9	71	1.0	54	1.1	48	1.1	39	1.2	32	1.3
180	268	0.7	186	0.8	131	0.8	101	0.9	75	1.0	57	1.1	50	1.1	41	1.2	33	1.3

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 4.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	28	0.6	20	0.7	14	0.7	10	0.8	8	0.9	6	0.9	5	1.1				
20	37	0.6	27	0.7	19	0.7	14	0.8	11	0.8	8	0.9	6	1.0	6	1.1		
25	46	0.6	33	0.7	23	0.7	17	0.8	13	0.8	11	0.9	8	1.0	7	1.1	6	1.2
30	55	0.6	40	0.7	28	0.7	20	0.8	16	0.8	13	0.9	10	1.0	8	1.1	7	1.2
35	64	0.6	46	0.7	32	0.7	24	0.8	18	0.8	15	0.9	11	1.0	10	1.1	8	1.2
40	73	0.6	52	0.7	37	0.7	27	0.8	21	0.8	17	0.9	13	1.0	11	1.0	9	1.1
45	82	0.6	59	0.7	41	0.7	30	0.8	23	0.8	19	0.9	14	1.0	12	1.1	10	1.1
50	91	0.6	65	0.7	46	0.7	34	0.8	26	0.8	21	0.9	16	1.0	14	1.1	11	1.1
55	100	0.6	72	0.7	50	0.7	37	0.8	29	0.8	23	0.9	17	1.0	15	1.0	12	1.1
60	109	0.6	78	0.7	55	0.7	40	0.8	31	0.8	25	0.9	19	1.0	16	1.0	13	1.1
65	117	0.6	84	0.7	59	0.7	44	0.8	34	0.8	27	0.9	20	1.0	18	1.1	14	1.1
70	126	0.6	90	0.7	63	0.7	47	0.8	36	0.8	29	0.9	22	1.0	19	1.0	15	1.1
75	135	0.6	97	0.7	68	0.7	50	0.8	39	0.8	31	0.8	24	1.0	20	1.0	17	1.1
80	143	0.6	103	0.7	72	0.7	53	0.8	41	0.8	33	0.9	25	1.0	21	1.0	18	1.1
90	161	0.6	115	0.7	81	0.7	60	0.8	46	0.8	37	0.9	28	1.0	24	1.0	20	1.1
100	178	0.6	128	0.7	90	0.7	66	0.8	51	0.8	41	0.9	31	1.0	27	1.0	22	1.1
110	195	0.6	140	0.7	99	0.7	73	0.8	56	0.8	45	0.9	34	1.0	29	1.0	24	1.1
120	213	0.6	153	0.7	107	0.7	79	0.8	61	0.8	49	0.9	37	1.0	32	1.0	26	1.1
130	230	0.6	165	0.7	116	0.7	86	0.8	66	0.8	53	0.9	40	1.0	35	1.0	28	1.1
140	247	0.6	177	0.7	125	0.7	92	0.8	71	0.8	57	0.9	43	1.0	37	1.0	31	1.1
150	264	0.6	189	0.7	133	0.7	99	0.8	76	0.8	61	0.9	47	1.0	40	1.0	33	1.1
160	280	0.6	201	0.7	142	0.7	105	0.8	81	0.8	65	0.9	50	1.0	42	1.0	35	1.1
170	297	0.6	213	0.7	150	0.7	112	0.8	86	0.8	69	0.9	53	1.0	45	1.0	37	1.1
180	314	0.6	225	0.7	159	0.7	118	0.8	91	0.8	73	0.9	56	1.0	48	1.0	39	1.1

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 5.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	29	0.6	21	0.6	15	0.7	12	0.7	9	0.8	7	0.8	6	0.9	5	1.0		
20	39	0.6	28	0.6	20	0.7	16	0.7	12	0.8	10	0.8	8	0.9	6	1.0	5	1.1
25	49	0.6	35	0.6	25	0.7	20	0.7	15	0.8	12	0.8	10	0.9	8	1.0	7	1.0
30	58	0.6	42	0.6	30	0.7	24	0.7	18	0.8	14	0.8	11	0.9	9	1.0	8	1.0
35	68	0.6	49	0.6	35	0.7	28	0.7	21	0.8	17	0.8	13	0.9	11	0.9	9	1.0
40	77	0.6	56	0.6	40	0.7	32	0.7	24	0.8	19	0.8	15	0.9	12	0.9	10	1.0
45	86	0.6	63	0.6	44	0.7	36	0.7	27	0.8	21	0.8	17	0.9	14	0.9	12	1.0
50	96	0.6	69	0.6	49	0.7	40	0.7	30	0.8	24	0.8	19	0.9	15	0.9	13	1.0
55	105	0.6	76	0.6	54	0.7	44	0.7	33	0.8	26	0.8	21	0.9	17	0.9	14	1.0
60	114	0.6	83	0.6	59	0.7	48	0.7	36	0.8	28	0.8	22	0.9	18	0.9	15	1.0
65	123	0.6	89	0.6	63	0.7	52	0.7	38	0.8	31	0.8	24	0.9	19	0.9	17	1.0
70	132	0.6	96	0.6	68	0.7	56	0.7	41	0.8	33	0.8	26	0.9	21	0.9	18	1.0
75	142	0.6	102	0.6	73	0.7	59	0.7	44	0.8	35	0.8	28	0.9	22	0.9	19	1.0
80	151	0.6	109	0.6	78	0.7	63	0.7	47	0.8	37	0.8	30	0.9	24	0.9	20	1.0
90	169	0.6	122	0.6	87	0.7	71	0.7	53	0.8	42	0.8	33	0.9	27	0.9	23	1.0
100	187	0.6	136	0.6	97	0.7	79	0.7	59	0.8	47	0.8	37	0.9	30	0.9	26	1.0
110	205	0.6	149	0.6	106	0.7	86	0.7	64	0.8	51	0.8	41	0.9	33	0.9	28	1.0
120	223	0.6	162	0.6	115	0.7	94	0.7	70	0.8	56	0.8	44	0.9	35	0.9	31	1.0
130	241	0.6	175	0.6	125	0.7	102	0.7	76	0.8	60	0.8	48	0.9	38	0.9	33	1.0
140	259	0.6	188	0.6	134	0.7	109	0.7	81	0.8	65	0.8	52	0.9	41	0.9	36	1.0
150	276	0.6	201	0.6	143	0.7	117	0.7	87	0.8	69	0.8	55	0.9	44	0.9	38	1.0
160	294	0.6	213	0.6	152	0.7	124	0.7	93	0.8	74	0.8	59	0.9	47	0.9	40	1.0
170	311	0.6	226	0.6	162	0.7	132	0.7	98	0.8	78	0.8	62	0.9	50	0.9	43	1.0
180	329	0.6	239	0.6	171	0.7	139	0.7	104	0.8	83	0.8	66	0.9	53	0.9	45	1.0

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 6.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	35	0.5	23	0.6	17	0.6	13	0.7	10	0.7	8	0.8	7	0.8	5	0.9	4	1.0
20	46	0.5	30	0.6	22	0.6	17	0.7	13	0.7	11	0.7	9	0.8	7	0.9	6	1.0
25	57	0.5	37	0.6	28	0.6	21	0.7	17	0.7	13	0.7	11	0.8	9	0.9	7	0.9
30	69	0.5	45	0.6	33	0.6	25	0.7	20	0.7	16	0.7	13	0.8	10	0.9	8	0.9
35	80	0.5	52	0.6	38	0.6	29	0.7	23	0.7	19	0.7	15	0.8	12	0.9	10	0.9
40	91	0.5	59	0.6	44	0.6	33	0.7	26	0.7	21	0.7	17	0.8	14	0.9	11	0.9
45	102	0.5	67	0.6	49	0.6	37	0.7	30	0.7	24	0.7	19	0.8	16	0.9	13	0.9
50	113	0.5	74	0.6	54	0.6	42	0.7	33	0.7	26	0.7	22	0.8	17	0.9	14	0.9
55	123	0.5	81	0.6	60	0.6	46	0.7	36	0.7	29	0.7	24	0.8	19	0.8	15	0.9
60	134	0.5	88	0.6	65	0.6	50	0.7	39	0.7	32	0.7	26	0.8	21	0.8	17	0.9
65	145	0.5	95	0.6	70	0.6	54	0.7	42	0.7	34	0.7	28	0.8	22	0.9	18	0.9
70	155	0.5	102	0.6	75	0.6	58	0.7	45	0.7	37	0.7	30	0.8	24	0.9	19	0.9
75	166	0.5	109	0.6	81	0.6	62	0.7	49	0.7	39	0.7	32	0.8	26	0.8	21	0.9
80	176	0.5	116	0.6	86	0.6	65	0.7	52	0.7	42	0.7	34	0.8	27	0.9	22	0.9
90	198	0.5	130	0.6	96	0.6	73	0.7	58	0.7	47	0.7	38	0.8	31	0.8	25	0.9
100	219	0.5	144	0.6	107	0.6	81	0.7	64	0.7	52	0.7	42	0.8	34	0.9	28	0.9
110	240	0.5	158	0.6	117	0.6	89	0.7	71	0.7	57	0.7	47	0.8	37	0.8	30	0.9
120	261	0.5	172	0.6	127	0.6	97	0.7	77	0.7	62	0.7	51	0.8	41	0.8	33	0.9
130	282	0.5	185	0.6	138	0.6	105	0.7	83	0.7	67	0.7	55	0.8	44	0.8	36	0.9
140	302	0.5	199	0.6	148	0.6	113	0.7	89	0.7	72	0.7	59	0.8	47	0.8	38	0.9
150	323	0.5	213	0.6	158	0.6	121	0.7	96	0.7	77	0.7	63	0.8	50	0.8	41	0.9
160	343	0.5	226	0.6	168	0.6	129	0.7	102	0.7	82	0.7	67	0.8	54	0.9	44	0.9
170	363	0.5	240	0.6	178	0.6	136	0.7	108	0.7	87	0.7	71	0.8	57	0.8	46	0.9
180	383	0.5	253	0.6	188	0.6	144	0.7	114	0.7	92	0.7	75	0.8	60	0.9	49	0.9

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 8.0 Percent

Q cfs	V = 2.0		V = 2.5		V = 3.0		V = 3.5		V = 4.0		V = 4.5		V = 5.0		V = 5.5		V = 6.0	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D	T	D
15	37	0.5	27	0.5	19	0.5	15	0.6	12	0.6	9	0.7	8	0.7	6	0.7	5	0.8
20	49	0.5	35	0.5	25	0.5	20	0.6	16	0.6	13	0.7	10	0.7	9	0.7	7	0.8
25	61	0.5	44	0.5	31	0.5	25	0.6	19	0.6	16	0.7	13	0.7	11	0.7	9	0.8
30	73	0.5	53	0.5	37	0.5	30	0.6	23	0.6	19	0.7	16	0.7	13	0.7	11	0.8
35	85	0.5	61	0.5	43	0.5	35	0.6	27	0.6	22	0.6	18	0.7	15	0.7	12	0.8
40	97	0.5	70	0.5	49	0.5	40	0.6	31	0.6	25	0.6	21	0.7	17	0.7	14	0.8
45	109	0.5	78	0.5	55	0.5	45	0.6	35	0.6	28	0.6	23	0.7	19	0.7	16	0.8
50	120	0.5	87	0.5	61	0.5	50	0.6	38	0.6	31	0.7	26	0.7	21	0.7	17	0.8
55	132	0.5	95	0.5	67	0.5	55	0.6	42	0.6	34	0.7	28	0.7	23	0.7	19	0.8
60	143	0.5	103	0.5	73	0.5	60	0.6	46	0.6	37	0.7	31	0.7	25	0.7	21	0.8
65	155	0.5	111	0.5	79	0.5	65	0.6	50	0.6	40	0.7	33	0.7	27	0.7	23	0.8
70	166	0.5	120	0.5	85	0.5	69	0.6	53	0.6	43	0.6	36	0.7	29	0.7	24	0.8
75	177	0.5	128	0.5	91	0.5	74	0.6	57	0.6	46	0.7	38	0.7	31	0.7	26	0.8
80	188	0.5	136	0.5	96	0.5	79	0.6	61	0.6	49	0.6	41	0.7	33	0.7	28	0.8
90	211	0.5	152	0.5	108	0.6	88	0.6	68	0.6	55	0.7	46	0.7	37	0.7	31	0.8
100	234	0.5	168	0.5	120	0.6	98	0.6	75	0.6	61	0.7	51	0.7	41	0.7	34	0.8
110	256	0.5	185	0.5	131	0.6	108	0.6	83	0.6	67	0.7	57	0.7	46	0.7	38	0.8
120	278	0.5	201	0.5	143	0.6	117	0.6	90	0.6	73	0.7	61	0.7	50	0.7	41	0.8
130	300	0.5	217	0.5	154	0.6	126	0.6	97	0.6	78	0.7	65	0.7	54	0.7	44	0.8
140	322	0.5	233	0.5	166	0.6	136	0.6	104	0.6	84	0.7	70	0.7	58	0.7	48	0.8
150	344	0.5	248	0.5	177	0.6	145	0.6	112	0.6	90	0.7	75	0.7	62	0.7	51	0.8
160	366	0.5	264	0.5	188	0.6	154	0.6	119	0.6	96	0.7	80	0.7	66	0.7	54	0.8
170	387	0.5	280	0.5	199	0.6	164	0.6	126	0.6	102	0.7	85	0.7	70	0.7	58	0.8
180	408	0.5	295	0.5	210	0.6	173	0.6	133	0.6	107	0.7	90	0.7	74	0.7	61	0.8

Q = Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D = Depth in Feet

V for Retardance "D",
T and D for Retardance "C"

Parabolic Waterway Design

Grade 10.0 Percent

Q cfs	V = 2.0 T	V = 2.0 D	V = 2.5 T	V = 2.5 D	V = 3.0 T	V = 3.0 D	V = 3.5 T	V = 3.5 D	V = 4.0 T	V = 4.0 D	V = 4.5 T	V = 4.5 D	V = 5.0 T	V = 5.0 D	V = 5.5 T	V = 5.5 D	V = 6.0 T	V = 6.0 D
15	45	0.4	33	0.5	23	0.5	17	0.5	13	0.6	11	0.6	9	0.6	7	0.7	6	0.7
20	60	0.4	43	0.5	30	0.5	22	0.5	18	0.6	14	0.6	12	0.6	10	0.7	8	0.7
25	75	0.4	54	0.5	38	0.5	28	0.5	22	0.6	18	0.6	15	0.6	12	0.7	10	0.7
30	89	0.4	64	0.5	45	0.5	33	0.5	27	0.6	21	0.6	18	0.6	15	0.6	12	0.7
35	104	0.4	75	0.5	53	0.5	38	0.5	31	0.6	25	0.6	21	0.6	17	0.7	14	0.7
40	118	0.4	85	0.5	60	0.5	44	0.5	35	0.6	28	0.6	24	0.6	20	0.7	16	0.7
45	132	0.4	95	0.5	67	0.5	49	0.5	40	0.6	32	0.6	27	0.6	22	0.7	18	0.7
50	146	0.4	105	0.5	74	0.5	54	0.5	44	0.6	35	0.6	30	0.6	24	0.7	20	0.7
55	160	0.4	115	0.5	82	0.5	60	0.5	48	0.6	39	0.6	32	0.6	27	0.6	22	0.7
60	174	0.4	125	0.5	87	0.5	65	0.5	52	0.6	42	0.6	35	0.6	29	0.7	24	0.7
65	188	0.4	135	0.5	96	0.5	70	0.5	57	0.6	45	0.6	38	0.6	32	0.7	26	0.7
70	201	0.4	145	0.5	103	0.5	75	0.5	61	0.6	49	0.6	41	0.6	34	0.7	28	0.7
75	215	0.4	153	0.5	110	0.5	80	0.5	65	0.6	52	0.6	44	0.6	36	0.7	30	0.7
80	228	0.4	164	0.5	116	0.5	85	0.5	69	0.6	55	0.6	47	0.6	39	0.7	32	0.7
90	255	0.4	184	0.5	131	0.5	96	0.5	76	0.6	62	0.6	52	0.6	43	0.7	36	0.7
100	282	0.4	204	0.5	145	0.5	106	0.5	86	0.6	69	0.6	58	0.6	48	0.7	40	0.7
110	309	0.4	223	0.5	158	0.5	116	0.5	94	0.6	76	0.6	64	0.6	53	0.7	44	0.7
120	336	0.4	242	0.5	172	0.5	126	0.5	103	0.6	82	0.6	69	0.6	57	0.7	48	0.7
130	362	0.4	262	0.5	186	0.5	137	0.5	111	0.6	89	0.6	75	0.6	62	0.7	52	0.7
140	388	0.4	281	0.5	200	0.5	147	0.5	119	0.6	95	0.6	81	0.6	67	0.7	56	0.7
150	414	0.4	299	0.5	213	0.5	157	0.5	127	0.6	102	0.6	86	0.6	71	0.7	60	0.7
160	440	0.4	318	0.5	227	0.5	166	0.5	135	0.6	108	0.6	92	0.6	76	0.7	64	0.7
170	466	0.4	337	0.5	240	0.5	176	0.5	143	0.6	115	0.6	97	0.6	80	0.7	67	0.7
180	491	0.4	355	0.5	253	0.5	186	0.5	151	0.6	121	0.6	103	0.6	85	0.7	71	0.7

Q Flow in Cubic Feet per Second, V = Velocity in Feet per Second, T = Top Width in Feet
D Depth in Feet

T[illegible] Channel Design

[illegible] Grade 0.5 Percent   Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b [illegible] D	b [illegible] V	b [illegible] D	b [illegible] V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	2.1	1.1	[illegible]	1.1	1.6	1.0	1.5	1.0	1.3	0.9	1.3	0.8	1.2	0.8	1.2	0.7
20	2.3	1.3	[illegible]	1.3	1.7	1.2	[illegible]	1.2	1.4	1.1	1.4	1.0	1.3	0.9	1.2	0.9
25	2.4	1.5	[illegible]	1.5	1.8	1.4	1.7	1.3	1.5	1.2	1.4	1.2	1.4	1.1	1.3	1.0
30	2.5	1.7	[illegible]	1.6	1.9	1.6	1.7	1.5	1.6	1.4	1.5	1.3	1.4	1.2	1.4	1.2
35	2.7	1.8	[illegible]	1.8	[illegible]	1.7	[illegible]	1.6	1.7	1.5	1.6	1.5	1.5	1.4	1.4	1.3
40	2.8	1.9	[illegible]	1.9	2.1	1.8	[illegible]	1.8	1.8	1.7	1.7	1.6	1.6	1.5	1.5	1.4
45	2.9	2.0	[illegible]	2.0	2.2	1.9	2.0	1.9	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.5
50	[illegible]	2.1	[illegible]	2.1	2.3	2.1	2.1	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.6
55	3.0	2.2	2.7	2.2	2.4	2.2	2.2	2.1	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7
60	3.1	2.3	2.8	2.3	2.5	2.2	2.2	2.2	2.0	2.1	1.9	2.0	1.8	1.9	1.7	1.8
65	3.2	2.4	2.8	2.4	2.5	2.3	2.3	2.2	2.1	2.2	2.0	2.1	1.9	2.0	1.8	1.9
70	3.3	2.5	[illegible]	2.4	2.6	2.4	2.4	2.3	2.2	2.2	2.0	2.2	1.9	2.1	1.8	2.0
75	3.4	2.5	[illegible]	2.5	2.7	2.5	2.4	2.4	2.2	2.3	2.1	2.2	1.9	2.1	1.8	2.1
80	3.4	2.6	3.1	2.6	2.7	2.5	2.5	2.5	2.3	2.4	2.1	2.3	2.0	2.2	1.9	2.1
90	3.6	2.7	3.2	2.7	2.9	2.7	2.6	2.6	2.4	2.5	2.2	2.4	2.1	2.3	2.0	2.3
100	3.7	2.8	[illegible]	2.8	3.0	2.8	2.7	2.7	2.5	2.7	2.3	2.6	2.2	2.5	2.1	2.4
110	3.9	2.9	[illegible]	2.9	3.1	2.9	2.8	2.8	2.6	2.8	2.4	2.7	2.3	2.6	2.2	2.5
120	4.0	3.1	3.5	3.0	3.2	3.0	2.9	3.0	2.7	2.9	2.5	2.8	2.4	2.7	2.2	2.6
130	4.1	3.1	3.7	3.1	3.3	3.1	3.0	3.0	2.8	3.0	2.6	2.9	2.5	2.8	2.3	2.7
140	4.2	3.2	3.8	3.2	3.4	3.2	3.1	3.1	2.9	3.1	2.7	3.0	2.5	2.9	2.4	2.8
150	4.3	3.3	[illegible]	3.3	3.5	3.3	3.2	3.2	3.0	3.1	2.8	3.1	2.6	3.0	2.5	2.9
160	4.4	3.4	4.0	3.4	3.6	3.4	3.3	3.3	3.1	3.2	2.9	3.2	2.7	3.1	2.5	3.0
170	4.5	3.5	4.1	3.5	3.7	3.4	3.4	3.4	3.1	3.3	2.9	3.2	2.8	3.2	2.6	3.1
180	4.6	3.6	4.1	3.6	3.8	3.5	3.5	3.5	3.2	3.4	3.0	3.3	2.8	3.2	2.7	3.2
190	4.6	3.6	[illegible]	3.6	3.9	3.6	3.6	3.5	3.3	3.5	3.1	3.4	2.9	3.3	2.7	3.2
200	4.7	3.7	[illegible]	3.7	3.9	3.7	3.6	3.6	3.4	3.5	3.2	3.5	3.0	3.4	2.8	3.3
220	4.9	3.8	[illegible]	3.8	4.1	3.8	3.8	3.7	3.5	3.7	3.3	3.6	3.1	3.5	2.9	3.4
240	5.0	3.9	[illegible]	3.9	4.2	3.9	3.9	3.8	3.6	3.8	3.4	3.7	3.2	3.6	3.0	3.6
260	5.2	4.0	4.8	4.0	4.4	4.0	4.1	4.0	3.8	3.9	3.5	3.8	3.3	3.8	3.2	3.7
280	5.3	4.1	4.9	4.1	4.5	4.1	4.2	4.1	3.9	4.0	3.7	4.0	3.6	3.9	3.3	3.8
300	5.5	4.2	5.0	4.2	4.7	4.2	4.3	4.2	4.0	4.1	3.8	4.1	3.6	4.0	3.4	3.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance   Grade 0.5 Percent   Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.7	1.6	1.5	1.5	1.3	1.4	1.1	1.3	1.1	1.1	1.0	1.0	1.0	1.0	0.9	0.9
20	1.9	1.8	1.6	1.8	1.4	1.7	1.2	1.5	1.1	1.4	1.1	1.3	1.0	1.2	1.0	1.1
25	2.0	2.1	1.7	2.0	1.5	1.9	1.3	1.8	1.2	1.6	1.2	1.5	1.1	1.4	1.0	1.3
30	2.1	2.3	1.8	2.2	1.6	2.1	1.4	1.9	1.3	1.8	1.2	1.7	1.2	1.6	1.1	1.5
35	2.2	2.5	1.9	2.4	1.6	2.3	1.5	2.1	1.4	2.0	1.3	1.9	1.2	1.8	1.2	1.7
40	2.3	2.6	2.0	2.5	1.7	2.5	1.6	2.3	1.4	2.2	1.3	2.0	1.3	1.9	1.2	1.8
45	2.4	2.8	2.0	2.7	1.8	2.6	1.6	2.5	1.5	2.3	1.4	2.2	1.3	2.1	1.2	2.0
50	2.5	2.9	2.1	2.8	1.9	2.7	1.7	2.6	1.5	2.5	1.4	2.3	1.4	2.2	1.3	2.1
55	2.6	3.0	2.2	2.9	1.9	2.9	1.8	2.7	1.6	2.6	1.5	2.5	1.4	2.3	1.3	2.2
60	2.6	3.1	2.3	3.1	2.0	2.9	1.8	2.9	1.7	2.7	1.5	2.6	1.5	2.4	1.4	2.3
65	2.7	3.2	2.4	3.1	2.1	3.1	1.9	2.9	1.7	2.8	1.6	2.7	1.5	2.6	1.4	2.4
70	2.8	3.3	2.4	3.3	2.1	3.2	2.0	3.1	1.8	2.9	1.6	2.8	1.5	2.7	1.5	2.6
75	2.8	3.4	2.5	3.4	2.2	3.3	2.0	3.1	1.8	3.0	1.7	2.9	1.6	2.8	1.5	2.7
80	2.9	3.5	2.5	3.4	2.3	3.4	2.0	3.3	1.9	3.1	1.7	3.0	1.7	2.9	1.5	2.7
90	3.0	3.6	2.7	3.6	2.4	3.5	2.1	3.4	2.0	3.3	1.8	3.2	1.7	3.0	1.6	2.9
100	3.1	3.8	2.8	3.8	2.5	3.7	2.2	3.6	2.1	3.5	1.9	3.3	1.8	3.2	1.7	3.1
110	3.3	4.0	2.9	3.9	2.6	3.8	2.3	3.7	2.1	3.6	2.0	3.5	1.9	3.3	1.8	3.2
120	3.4	4.1	3.0	4.0	2.7	4.0	2.4	3.9	2.2	3.7	2.1	3.6	1.9	3.5	1.8	3.4
130	3.5	4.2	3.1	4.1	2.8	4.1	2.5	4.0	2.3	3.9	2.1	3.7	2.0	3.6	1.9	3.5
140	3.6	4.3	3.2	4.3	2.8	4.2	2.6	4.1	2.4	4.0	2.2	3.9	2.1	3.8	1.9	3.6
150	3.7	4.4	3.3	4.4	2.9	4.3	2.7	4.2	2.4	4.1	2.3	4.0	2.1	3.9	2.0	3.7
160	3.7	4.5	3.3	4.5	3.0	4.4	2.7	4.4	2.5	4.2	2.3	4.1	2.2	4.0	2.1	3.9
170	3.8	4.6	3.4	4.6	3.1	4.5	2.8	4.4	2.6	4.3	2.4	4.2	2.2	4.1	2.1	4.0
180	3.9	4.7	3.5	4.7	3.1	4.6	2.9	4.5	2.7	4.4	2.5	4.3	2.3	4.2	2.2	4.1
190	4.0	4.8	3.6	4.8	3.2	4.7	2.9	4.7	2.7	4.5	2.5	4.4	2.4	4.3	2.2	4.2
200	4.1	4.9	3.6	4.9	3.3	4.8	3.0	4.7	2.8	4.6	2.6	4.5	2.4	4.4	2.3	4.2
220	4.2	5.1	3.8	5.0	3.4	5.0	3.1	4.9	2.9	4.8	2.7	4.7	2.5	4.6	2.4	4.4
240	4.3	5.2	3.9	5.2	3.6	5.1	3.3	5.1	3.0	4.9	2.8	4.9	2.6	4.7	2.5	4.6
260	4.4	5.4	4.0	5.3	3.7	5.3	3.4	5.2	3.1	5.1	2.9	5.0	2.7	4.9	2.6	4.8
280	4.6	5.5	4.1	5.5	3.8	5.4	3.5	5.4	3.2	5.2	3.0	5.1	2.8	5.0	2.7	4.9
300	4.7	5.6	4.3	5.6	3.9	5.6	3.6	5.5	3.3	5.4	3.1	5.3	2.9	5.2	2.8	5.1

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 1.0 Percent Side Slope 2:1

Bottom Width, b, in Feet

Q cfs	b = 2		b = 4		b = 6		b = 8		b = 10		b = 12		b = 14		b = 16	
	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V
15	1.4	2.2	1.2	2.0	1.0	1.8	0.9	1.7	0.9	1.5	0.8	1.4	0.8	1.2	0.7	1.1
20	1.5	2.5	1.3	2.4	1.1	2.2	1.0	2.0	0.9	1.8	0.9	1.7	0.8	1.5	0.8	1.4
25	1.7	2.8	1.4	2.7	1.2	2.5	1.1	2.3	1.0	2.1	0.9	2.0	0.9	1.8	0.8	1.7
30	1.8	3.1	1.5	3.0	1.3	2.8	1.1	2.6	1.0	2.4	1.0	2.2	0.9	2.0	0.9	1.9
35	1.9	3.3	1.6	3.2	1.3	3.0	1.2	2.8	1.1	2.6	1.0	2.4	1.0	2.3	0.9	2.1
40	1.9	3.5	1.6	3.4	1.4	3.2	1.3	3.0	1.1	2.8	1.1	2.6	1.0	2.5	1.0	2.3
45	2.0	3.7	1.7	3.6	1.5	3.4	1.3	3.2	1.2	3.0	1.1	2.8	1.1	2.7	1.0	2.5
50	2.1	3.9	1.8	3.7	1.5	3.6	1.4	3.4	1.3	3.2	1.2	3.0	1.1	2.8	1.0	2.7
55	2.2	4.0	1.8	3.9	1.6	3.7	1.4	3.5	1.3	3.3	1.2	3.2	1.1	3.0	1.1	2.8
60	2.2	4.2	1.9	4.1	1.7	3.9	1.5	3.7	1.3	3.5	1.3	3.3	1.2	3.1	1.1	3.0
65	2.3	4.3	1.9	4.2	1.7	4.0	1.5	3.9	1.4	3.6	1.3	3.5	1.2	3.3	1.1	3.1
70	2.4	4.4	2.0	4.3	1.8	4.2	1.6	4.0	1.4	3.8	1.3	3.6	1.2	3.4	1.2	3.3
75	2.4	4.5	2.1	4.5	1.8	4.3	1.6	4.1	1.5	3.9	1.4	3.7	1.3	3.5	1.2	3.4
80	2.5	4.6	2.1	4.5	1.9	4.4	1.7	4.2	1.5	4.0	1.4	3.9	1.3	3.7	1.2	3.5
90	2.6	4.9	2.2	4.8	2.0	4.6	1.7	4.5	1.6	4.3	1.5	4.1	1.4	3.9	1.3	3.7
100	2.7	5.1	2.3	5.0	2.0	4.9	1.8	4.7	1.7	4.5	1.5	4.3	1.4	4.1	1.4	3.9
110	2.8	5.2	2.4	5.2	2.1	5.0	1.9	4.9	1.7	4.7	1.6	4.5	1.5	4.3	1.4	4.1
120	2.9	5.4	2.5	5.4	2.2	5.2	2.0	5.0	1.8	4.9	1.7	4.7	1.6	4.5	1.5	4.3
130	3.0	5.6	2.6	5.5	2.3	5.4	2.1	5.2	1.9	5.0	1.7	4.9	1.6	4.7	1.5	4.5
140	3.0	5.7	2.7	5.6	2.4	5.5	2.1	5.4	1.9	5.2	1.8	5.0	1.7	4.8	1.6	4.7
150	3.1	5.9	2.7	5.8	2.4	5.6	2.2	5.5	2.0	5.4	1.8	5.2	1.7	5.0	1.6	4.8
160	3.2	6.0	2.8	6.0	2.5	5.8	2.2	5.7	2.1	5.5	1.9	5.3	1.8	5.1	1.7	4.9
170					2.6	6.0	2.3	5.8	2.1	5.6	2.0	5.5	1.8	5.2	1.7	5.1
180							2.4	5.9	2.2	5.8	2.0	5.6	1.9	5.4	1.8	5.2
190									2.2	5.9	2.1	5.7	1.9	5.5	1.8	5.4
200									2.3	6.0	2.1	5.8	2.0	5.6	1.9	5.4
220													2.1	5.9	2.0	5.7
240															2.0	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 2.0 Percent Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2		b = 4		b = 6		b = 8		b = 10		b = 12		b = 14		b = 16	
	D	V	D	V	D	V	D	V	D	V	D	V	D	V	D	V
15	1.2	3.0	0.9	2.7	0.8	2.4	0.7	2.1	0.7	1.9	0.7	1.7	0.6	1.6	0.6	1.4
20	1.3	3.4	1.0	3.2	0.9	2.9	0.8	2.6	0.7	2.3	0.7	2.1	0.7	1.0	0.6	1.8
25	1.4	3.8	1.1	3.6	1.0	3.3	0.9	3.0	0.8	2.7	0.7	2.5	0.7	2.3	0.7	2.1
30	1.5	4.2	1.2	3.9	1.0	3.6	0.9	3.3	0.8	3.1	0.8	2.8	0.7	2.6	0.7	2.4
35	1.6	4.4	1.3	4.2	1.1	3.9	1.0	3.6	0.9	3.3	0.8	3.1	0.8	2.9	0.7	2.7
40	1.6	4.7	1.3	4.5	1.1	4.2	1.0	3.9	0.9	3.6	0.9	3.4	0.8	3.1	0.8	2.9
45	1.7	4.9	1.4	4.7	1.2	4.5	1.1	4.2	1.0	3.9	0.9	3.6	0.8	3.4	0.8	3.2
50	1.8	5.2	1.5	5.0	1.2	4.7	1.1	4.4	1.0	4.1	0.9	3.9	0.9	3.6	0.8	3.4
55	1.8	5.4	1.5	5.1	1.3	4.9	1.2	4.6	1.0	4.3	1.0	4.0	0.9	3.8	0.9	3.6
60	1.9	5.5	1.6	5.3	1.4	5.1	1.2	4.8	1.1	4.5	1.0	4.2	0.9	4.0	0.9	3.8
65	1.9	5.7	1.6	5.5	1.4	5.3	1.2	5.0	1.1	4.7	1.0	4.4	1.0	4.2	0.9	4.0
70	2.0	5.9	1.7	5.7	1.4	5.5	1.3	5.2	1.2	4.9	1.1	4.6	1.0	4.3	1.0	4.1
75			1.7	5.9	1.5	5.6	1.3	5.3	1.2	5.0	1.1	4.7	1.0	4.5	1.0	4.3
80					1.5	5.8	1.4	5.5	1.2	5.2	1.1	4.9	1.1	4.7	1.0	4.4
90							1.4	5.8	1.3	5.5	1.2	5.2	1.1	5.0	1.1	4.7
100									1.4	5.8	1.3	5.5	1.2	5.2	1.1	5.0
110									1.4	6.0	1.3	5.8	1.2	5.5	1.1	5.2
120											1.4	6.0	1.3	5.7	1.2	5.4
130													1.3	5.9	1.2	5.7
140															1.3	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width,Feet, D = Depth,Feet.

Trapezoidal Channel Design

"C" Retardance Grade 3 Percent Side Slope = 2:1

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.0	3.5	0.8	3.2	0.7	2.8	0.6	2.5	0.6	2.2	0.6	2.0	0.5	1.8	0.5	1.7
20	1.1	4.1	0.9	3.7	0.8	3.4	0.7	3.0	0.7	2.7	0.6	2.5	0.6	2.3	0.6	2.1
25	1.2	4.5	1.0	4.2	0.8	3.8	0.8	3.5	0.7	3.2	0.7	2.9	0.6	2.6	0.6	2.5
30	1.3	4.9	1.1	4.6	0.9	4.2	0.8	3.8	0.7	3.5	0.7	3.2	0.7	3.0	0.6	2.8
35	1.4	5.3	1.1	4.9	1.0	4.6	0.9	4.2	0.8	3.9	0.7	3.6	0.7	3.3	0.7	3.1
40	1.5	5.6	1.2	5.3	1.0	4.9	0.9	4.5	0.8	4.2	0.8	3.9	0.7	3.6	0.7	3.3
45	1.5	5.9	1.2	5.6	1.1	5.2	0.9	4.8	0.9	4.5	0.8	4.2	0.8	3.9	0.7	3.6
50			1.3	5.9	1.1	5.4	1.0	5.1	0.9	4.7	0.8	4.4	0.8	4.1	0.7	3.9
55					1.2	5.7	1.0	5.4	0.9	5.0	0.9	4.7	0.8	4.4	0.8	4.1
60					1.2	5.9	1.2	5.6	1.0	5.2	0.9	4.9	0.8	4.6	0.8	4.3
65							1.1	5.8	1.0	5.4	0.9	5.1	0.9	4.8	0.8	4.5
70							1.1	6.0	1.0	5.6	1.0	5.3	0.9	5.0	0.8	4.7
75									1.1	5.8	1.0	5.5	0.9	5.1	0.9	4.9
80											1.0	5.6	0.9	5.3	0.9	5.0
90													1.0	5.6	1.0	5.4
100													1.0	6.0	1.0	5.7
110															1.0	6.0

(Bottom Width, b, in Feet)

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 4 Percent Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	1.0	4.0	0.8	3.6	0.7	3.2	0.6	2.8	0.5	2.4	0.5	2.2	0.5	2.0	0.5	1.8
20	1.1	4.6	0.8	4.2	0.7	3.8	0.6	3.3	0.6	3.0	0.6	2.7	0.5	2.5	0.5	2.3
25	1.1	5.1	0.9	4.8	0.8	4.3	0.7	3.8	0.6	3.5	0.6	3.1	0.6	2.9	0.5	2.7
30	1.2	5.6	1.0	5.2	0.8	4.7	0.7	4.3	0.7	3.9	0.6	3.6	0.6	3.3	0.6	3.0
35	1.3	5.9	1.0	5.6	0.9	5.1	0.8	4.7	0.7	4.3	0.7	3.9	0.6	3.6	0.6	3.4
40			1.1	5.9	0.9	5.4	0.8	5.0	0.8	4.6	0.7	4.2	0.6	3.9	0.6	3.7
45					1.0	5.8	0.9	5.4	0.8	4.9	0.7	4.6	0.7	4.3	0.6	4.0
50							0.9	5.6	0.8	5.2	0.8	4.9	0.7	4.6	0.7	4.2
55							0.9	5.9	0.8	5.5	0.8	5.1	0.7	4.8	0.7	4.5
60									0.9	5.8	0.8	5.4	0.8	5.0	0.7	4.8
65									0.9	6.0	0.8	5.6	0.8	5.3	0.7	5.0
70											0.9	5.9	0.9	5.5	0.8	5.2
75													0.9	5.7	0.8	5.4
80													0.9	5.9	0.8	5.6
90															0.9	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

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Trapezoidal Channel Design

"C" Retardance   Grade 5 Percent   Side Slope 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.9	4.4	0.7	3.9	0.6	3.4	0.6	3.0	0.5	2.6	0.5	2.3	0.5	2.1	0.5	2.0
20	1.0	5.1	0.8	4.6	0.7	4.1	0.6	3.6	0.6	3.2	0.5	2.9	0.5	2.7	0.5	2.4
25	1.1	5.6	0.9	5.2	0.7	4.6	0.6	4.2	0.6	3.7	0.6	3.4	0.5	3.1	0.5	2.9
30			0.9	5.6	0.8	5.1	0.7	4.6	0.6	4.2	0.6	3.9	0.6	3.5	0.5	3.3
35					0.8	5.5	0.7	5.1	0.7	4.6	0.6	4.2	0.6	3.9	0.6	3.6
40					0.9	5.9	0.8	5.4	0.7	5.0	0.7	4.6	0.6	4.3	0.6	4.0
45							0.8	5.7	0.7	5.3	0.7	5.0	0.6	4.6	0.6	4.3
50									0.8	5.6	0.7	5.3	0.7	4.9	0.6	4.6
55									0.9	6.0	0.7	5.5	0.7	5.2	0.7	4.9
60											0.8	5.8	0.7	5.4	0.7	5.1
65													0.7	5.7	0.7	5.3
70													0.8	5.9	0.7	5.6
75															0.7	5.8
80															0.8	6.0

Grade 6 Percent

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.9	4.8	0.7	4.2	0.6	3.6	0.5	3.2	0.5	2.8	0.5	2.5	0.4	2.3	0.4	2.1
20	0.9	5.4	0.7	4.9	0.6	4.4	0.6	3.8	0.5	3.4	0.5	3.1	0.5	2.8	0.5	2.6
25			0.8	5.6	0.7	4.9	0.6	4.4	0.6	4.0	0.5	3.6	0.5	3.3	0.5	3.1
30					0.7	5.5	0.7	4.9	0.6	4.5	0.6	4.1	0.5	3.7	0.5	3.5
35					0.8	5.9	0.7	5.4	0.6	4.9	0.6	4.5	0.6	4.2	0.5	3.8
40							0.7	5.8	0.7	5.3	0.6	4.9	0.7	4.5	0.6	4.2
45									0.7	5.6	0.6	5.2	0.6	4.9	0.6	4.6
50											0.7	5.6	0.6	5.2	0.6	4.9
55											0.7	5.8	0.7	5.5	0.6	5.1
60													0.7	5.8	0.6	5.4
65															0.7	5.7
70															0.7	5.9

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

Trapezoidal Channel Design

"C" Retardance Grade 8 Percent Side Slope = 2:1

Bottom Width, b, in Feet

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.8	5.3	0.6	4.7	0.5	4.1	0.5	3.5	0.4	3.1	0.4	2.8	0.4	2.5	0.4	2.3
20			0.7	5.5	0.6	4.8	0.5	4.2	0.5	3.8	0.5	3.4	0.4	3.1	0.4	2.8
25					0.6	5.5	0.6	4.9	0.5	4.4	0.5	4.0	0.5	3.6	0.4	3.3
30							0.6	5.5	0.5	4.9	0.5	4.5	0.5	4.2	0.5	3.8
35							0.6	6.0	0.6	5.5	0.5	5.0	0.5	4.6	0.5	4.2
40									0.6	5.9	0.6	5.4	0.5	5.0	0.5	4.6
45											0.6	5.7	0.6	5.4	0.5	5.0
50													0.6	5.7	0.5	5.3
55															0.6	5.7
60															0.6	6.0

Grade 10 Percent

Q cfs	b = 2 D	b = 2 V	b = 4 D	b = 4 V	b = 6 D	b = 6 V	b = 8 D	b = 8 V	b = 10 D	b = 10 V	b = 12 D	b = 12 V	b = 14 D	b = 14 V	b = 16 D	b = 16 V
15	0.7	5.9	0.6	5.1	0.5	4.4	0.4	3.8	0.4	3.4	0.4	3.0	0.4	2.6	0.4	2.4
20			0.6	6.0	0.5	5.2	0.5	4.6	0.4	4.1	0.4	3.7	0.4	3.4	0.4	3.1
25					0.6	6.0	0.5	5.3	0.5	4.7	0.4	4.3	0.4	3.9	0.4	3.6
30							0.6	5.9	0.5	5.3	0.5	4.9	0.5	4.4	0.4	4.1
35									0.5	5.8	0.5	5.4	0.5	4.9	0.5	4.6
40											0.5	5.8	0.5	5.3	0.5	5.0
45													0.5	5.7	0.5	5.4
50															0.5	5.7

Q = Flow, Cubic Feet per Second, V = Velocity, Feet per Second, b = Bottom Width, Feet, D = Depth, Feet.

APPENDIX B

Sample Design Procedure for Riprap-Lined Channels

This design of riprap-lined channels is from the National Cooperative Highway Research Program Report No. 108, entitled "Tentative Design Procedure for Riprap-Lined Channels." It is based on the tractive force method and covers the design of riprap in two basic channel shapes, trapezoidal and triangular. (19)

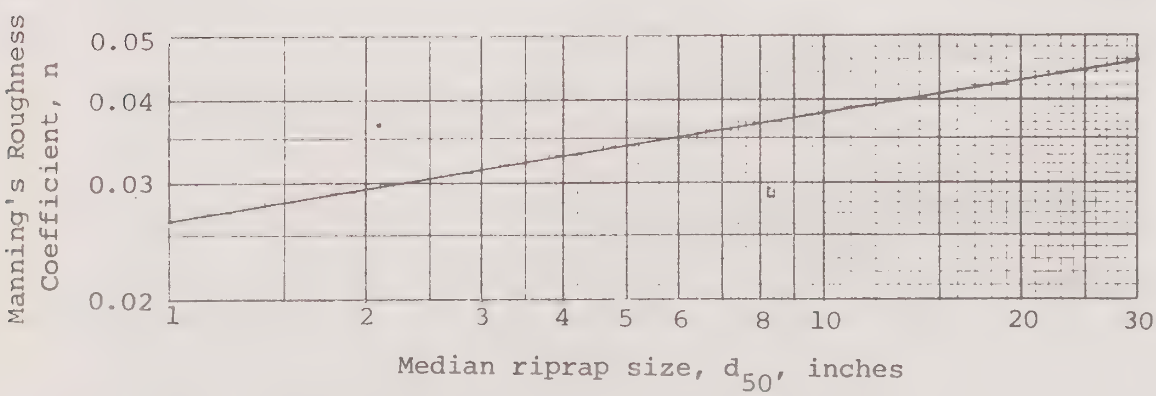
NOTE: This procedure is for the uniform flow in channels and is <u>not</u> to be used for design of riprap deenergizing devices immediately downstream from such high velocity devices as pipes and culverts. See the Standard and Specification for Storm Drain Outlet Protection.

The method in Report No. 108 (design procedure beginning on p. 18) gives a simple and direct solution to the design of trapezoidal channels including channel carrying capacity, channel geometry and the riprap lining. The publication is a very good reference and design aid.

The procedure presented in this Appendix is based on the assumption that the channel is already designed and the remaining problem is to determine the riprap size that would be stable in the channel. The designer would first determine the channel dimensions by the use of Manning's equation. The n value for use in Manning's equation is estimated by estimating a riprap size and then determining the corresponding n value for the riprapped channel from Curve 1, below.

Curve 1 - Manning's "n" for Riprap-Lined Channels

$$n = 0.0395(d_{50})^{1/6}$$



This sample design procedure is provided by the USDA, Soil Conservation Service.

When the channel dimensions are known the riprap can be designed (or an already completed design may be checked) as follows:

Trapezoidal Channels

1. Calculate the b/d ratio and enter curve 2 to find the P/R ratio.

2. Enter curve 3 with S_b, Q, and P/R to find median riprap diameter, d_{50}, for straight channels.

3. Enter curve 1 to find the actual n value corresponding to the d_{50} from step 2. If the estimated and actual n values are not in reasonable agreement another trial must be made.

4. For channels with bends, calculate the ratio B_s/R_o, where B_s is the channel surface width and R_o is the radius of the bend. Enter curve 4 and find the bend factor, F_B. Multiply the d_{50} for straight channels by the bend factor to determine riprap size to be used in bends. If the d_{50} for the bend is less than 1.1 times the d_{50} for the straight channel, then the size for straight channel may be used in the bend, otherwise the larger stone size calculated for the bend shall be used. The riprap shall extend across the full channel section and shall extend upstream and downstream from the ends of the curve a distance equal to five times the bottom width.

5. Enter curve 5 to determine maximum stable side slope of riprap surface.

Triangular Channels

1. Enter curve 3A with S_b, Q and Z and find the median riprap diameter, d_{50}, for straight channels.

2. Enter curve 1 to find the actual n value. If the estimated and actual n values are not in reasonable agreement another trial must be made.

3. For channels with bends, see step 4 under Trapezoidal channels.

The riprap size to be specified on the plans shall be the maximum stone size in the mixture which shall be 1.5 times the d_{50}. The thickness of the riprap layer is 1.5 times the maximum stone size, but not less than six inches. Freeboard shall be added to the channel depth and shall be not less than 0.2 times the depth of flow or 0.3 feet, whichever is greater.

Example:

Given:

Trapezoidal channel

$Q = 100$ cfs
$S = 0.01$ ft/ft.
Side slopes = 2.5:1
Mean bend radius, $R_o = 25'$
$n = .033$ (estimated and used to design the channel to find that $b = 6'$ and $d = 1.8'$)
Type of rock available is crushed stone.

Solution:

<u>Straight channel reach</u>

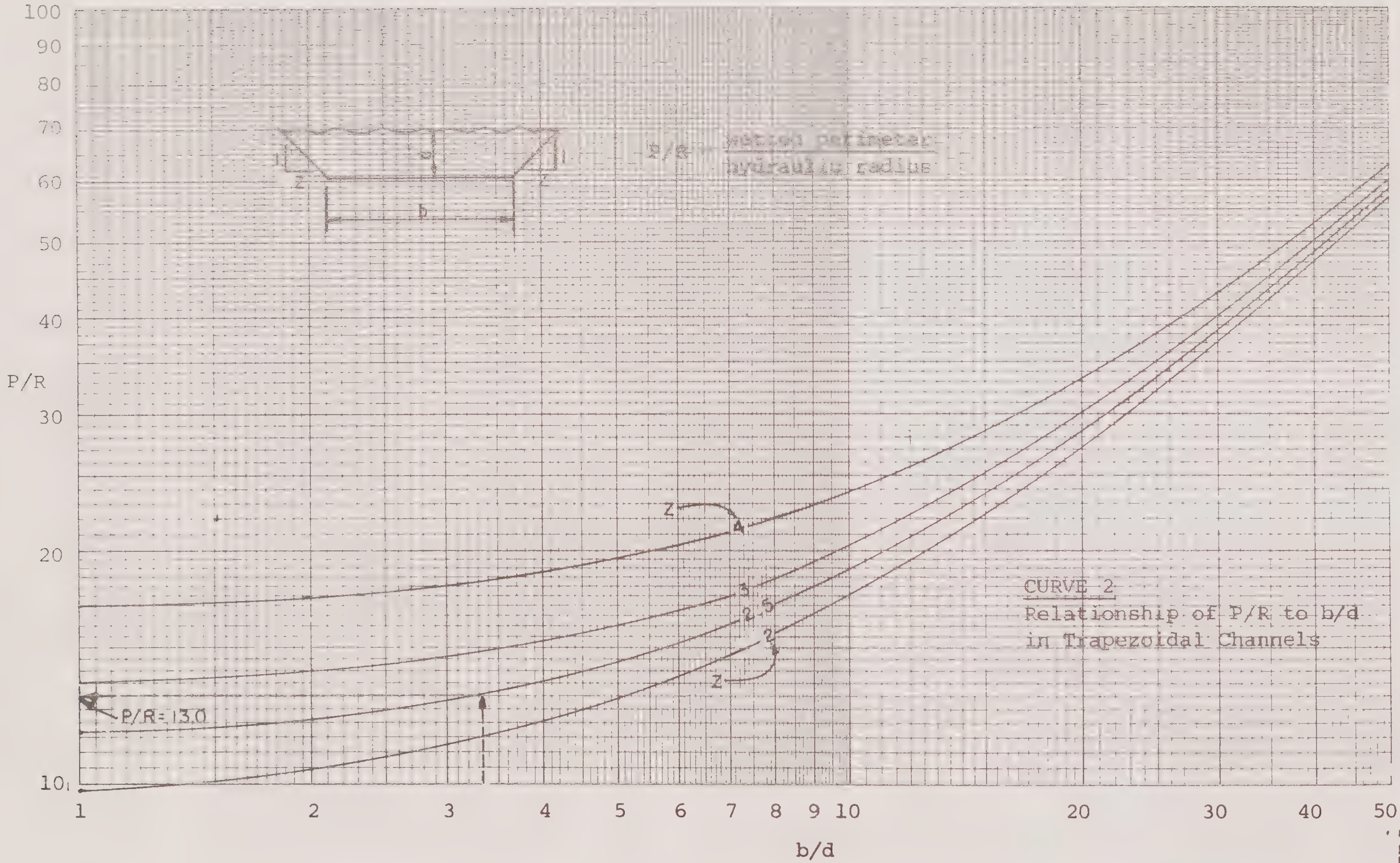
$b/d = 6/1.8 = 3.33$
from curve 2, $P/R = 13.0$
from curve 3, $d_{50} = 3.4"$
from curve 1, n (actual) = 0.032, which is reasonably close to the estimated n of 0.033.
Maximum riprap size = 1.5 x 3.4 = 5.1"
Riprap thickness = 1.5 x 5.1 = 7.7"
<u>Use 5" as maximum riprap size and 8" as riprap layer thickness</u>.

<u>Channel bend</u>

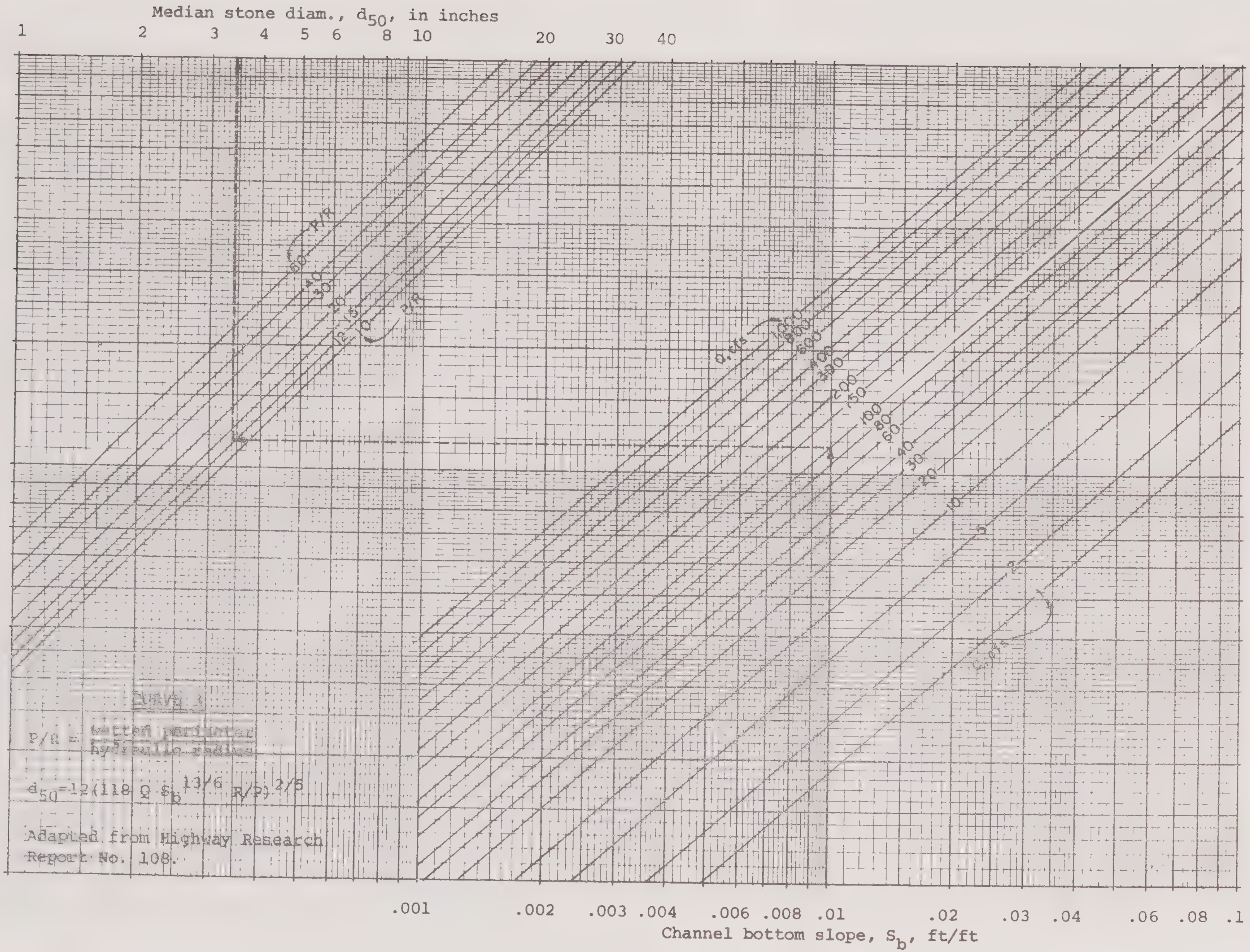
$B_s = b + 2zd = 6 + (2)(2.5)(1.8) = 15'$
$B_s/R_o = 12/25 = 0.60$
from curve 4, $F_B = 1.33$
$F_B = 1.33 > 1.1$, therefore the bend factor must be used.
Riprap size in bend, $d_{50} = 3.4 \times 1.33 = 4.52"$
Max. riprap size in bend = 4.52 x 1.5 = 6.78"
Riprap thickness = 10.2"
<u>Use 7" for max. riprap size and 10" for riprap layer thickness</u>.
The heavier riprap for the bend shall extend upstream and downstream from the ends of the bend a distance of (5)(6) = 30 feet.
From curve 5, it can be found that the riprap for $d_{50} = 3.4"$ and 4.52" will both be stable on a 2.5:1 side slope.

Freeboard = (0.2)(1.8) = .36' but not less than 0.3'
Therefore, minimum freeboard is 0.36'. <u>Use 0.4'</u>

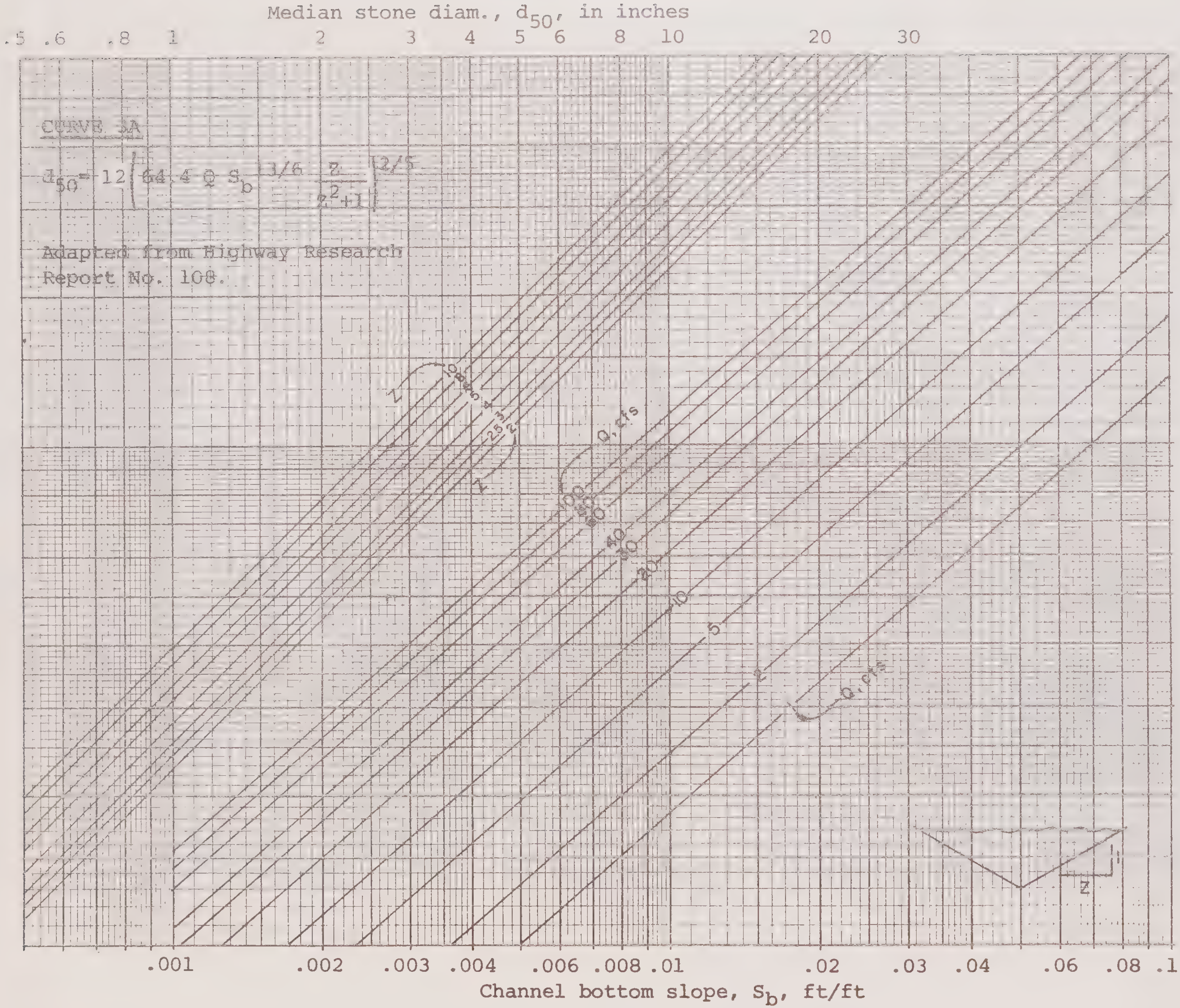
P/R FOR TRAPEZOIDAL CHANNELS



MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRAPEZOIDAL CHANNELS



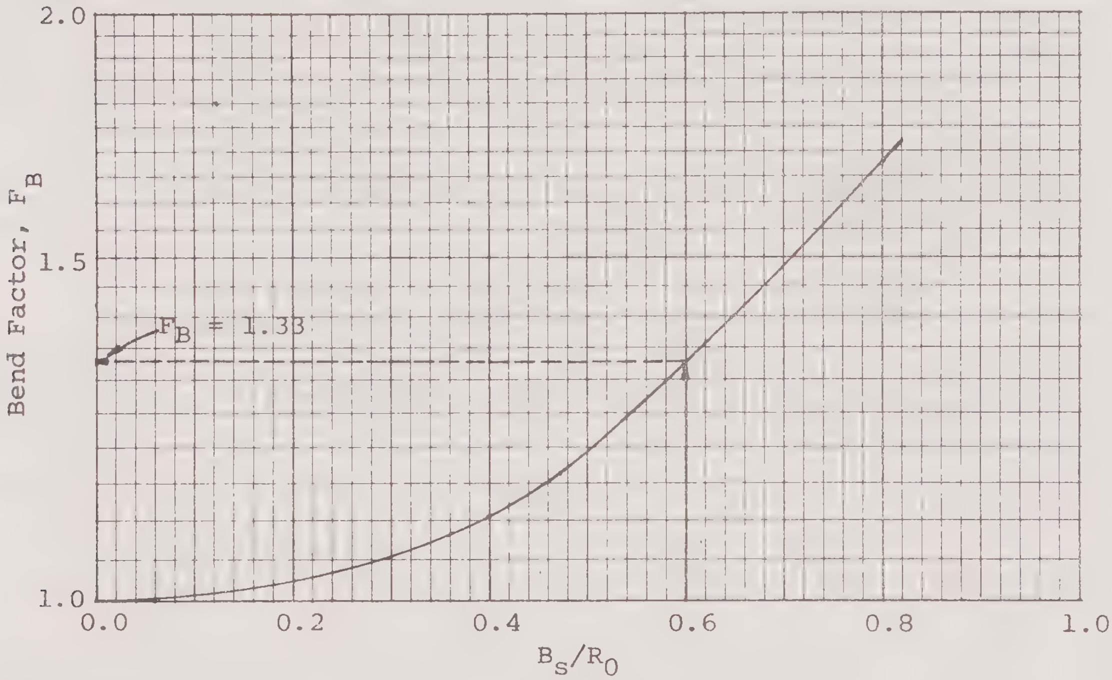
MEDIAN RIPRAP DIAMETER FOR STRAIGHT TRIANGULAR CHANNELS



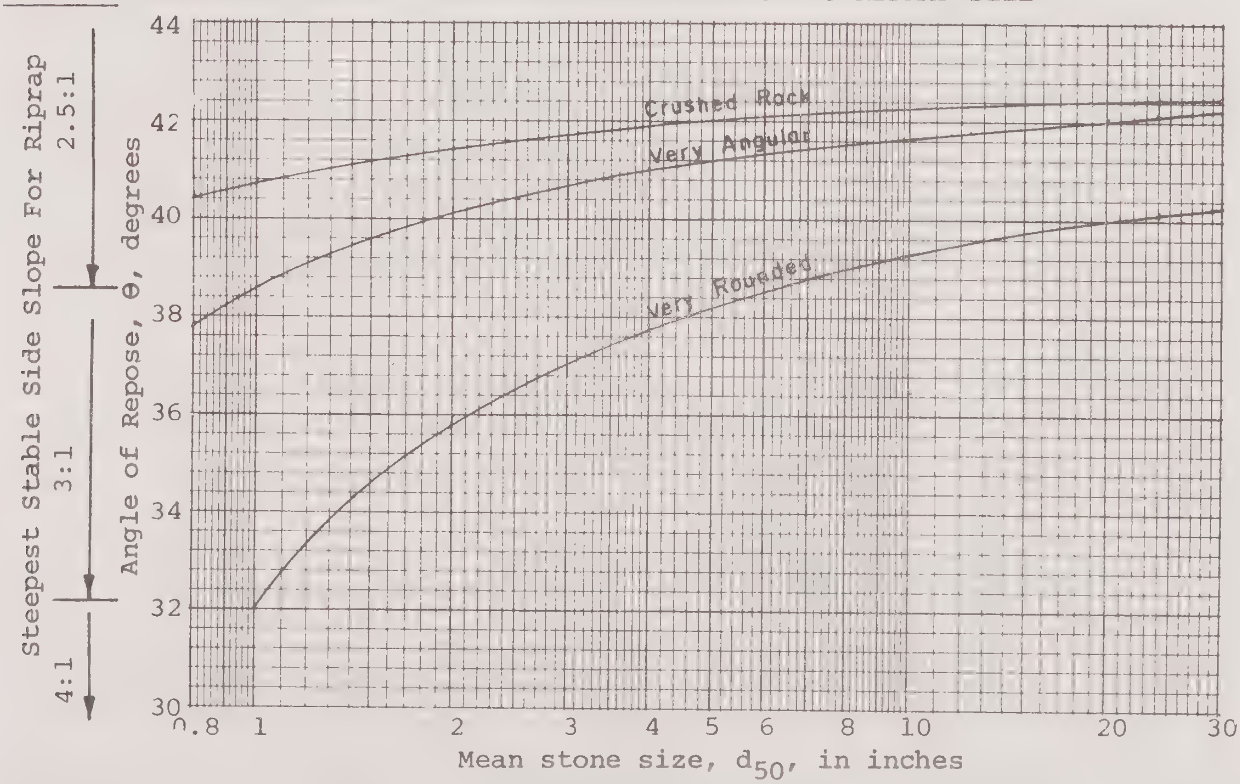
CURVE 4 - RIPRAP SIZE CORRECTION FACTOR FOR FLOW IN CHANNEL BENDS

d_{50}(for bend) = d_{50}(for straight) X F_B
B_s = channel surface width
R_o = mean radius of bend

Adapted from Highway Research Report No. 108.



CURVE 5 - MAXIMUM RIPRAP SIDE SLOPE WITH RESPECT TO RIPRAP SIZE



APPENDIX C

Sample Design of Outlet Protection

Outlet protection as presented here is a level apron of sufficient length and flare such that the expanding flow (from pipe or conduit to channel) loses sufficient velocity and energy that it will not erode the next downstream channel reach. The design curves are based on circular conduits flowing full. The curves provide the apron size and if riprap is to be used, the minimum d_{50} size for the riprap. There are two curves, one for a low or minimum tailwater condition and the other a high or maximum tailwater condition. The minimum condition applies to a tailwater surface elevation less than the center of the pipe whereas the maximum condition applies to a tailwater surface elevation equal to or higher than the center of the pipe.

The first requirement in using this procedure is to determine the tailwater condition as required in the Standard and Specifications. Then, for circular conduits, enter the appropriate chart with the discharge and the pipe diameter to find the riprap size and apron length. Then calculate apron width.

Example 1:

A circular conduit is flowing full
Q = 280 cfs, diam. = 66", and tailwater (surface) is 2 ft. above pipe invert.

This is a minimum tailwater condition.
Read d_{50} = 1.2', and apron length = 38'
Apron width = diam + L_a = 38 + 5.5 = 43.5'
Maximum stone size in the riprap mixture = 1.5 x d_{50} = 1.5 x 1.2 = 1.8'.

The curves may also be used for the design of outlet protection for rectangular conduits but the procedure is slightly different. Depth of flow and velocity are the two flow parameters to be used. Enter the lower set of curves with velocity and depth (using the diameter curves for depth), then read to the right to find d_{50} and up and left for the length of apron. To find the apron width substitute conduit width for diameter in the apron width equations.

Example 2:

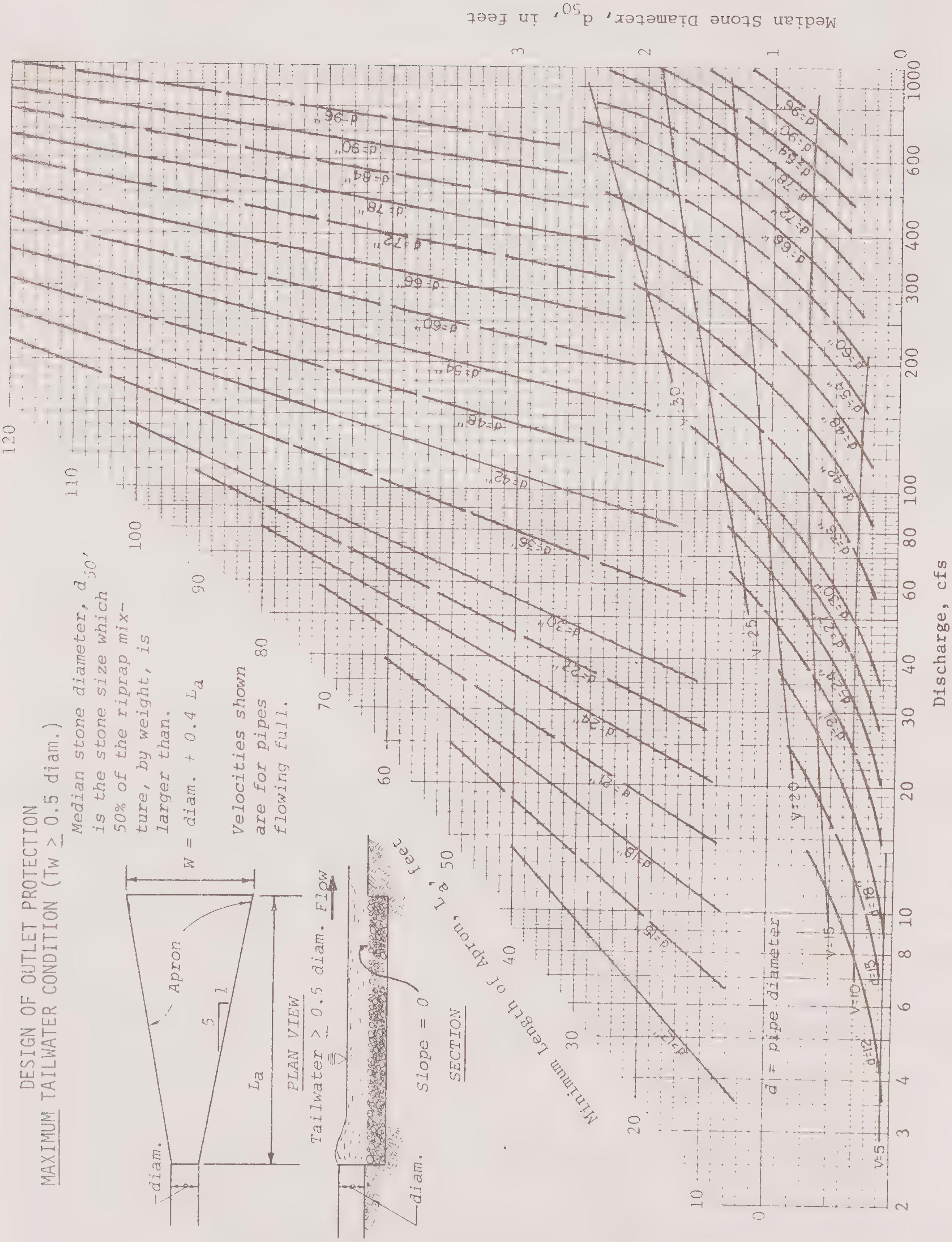
A concrete box 5.5' x 10' is flowing 5.0' deep, Q = 600 cfs and tailwater surface 5' above invert (Max. tailwater condition).

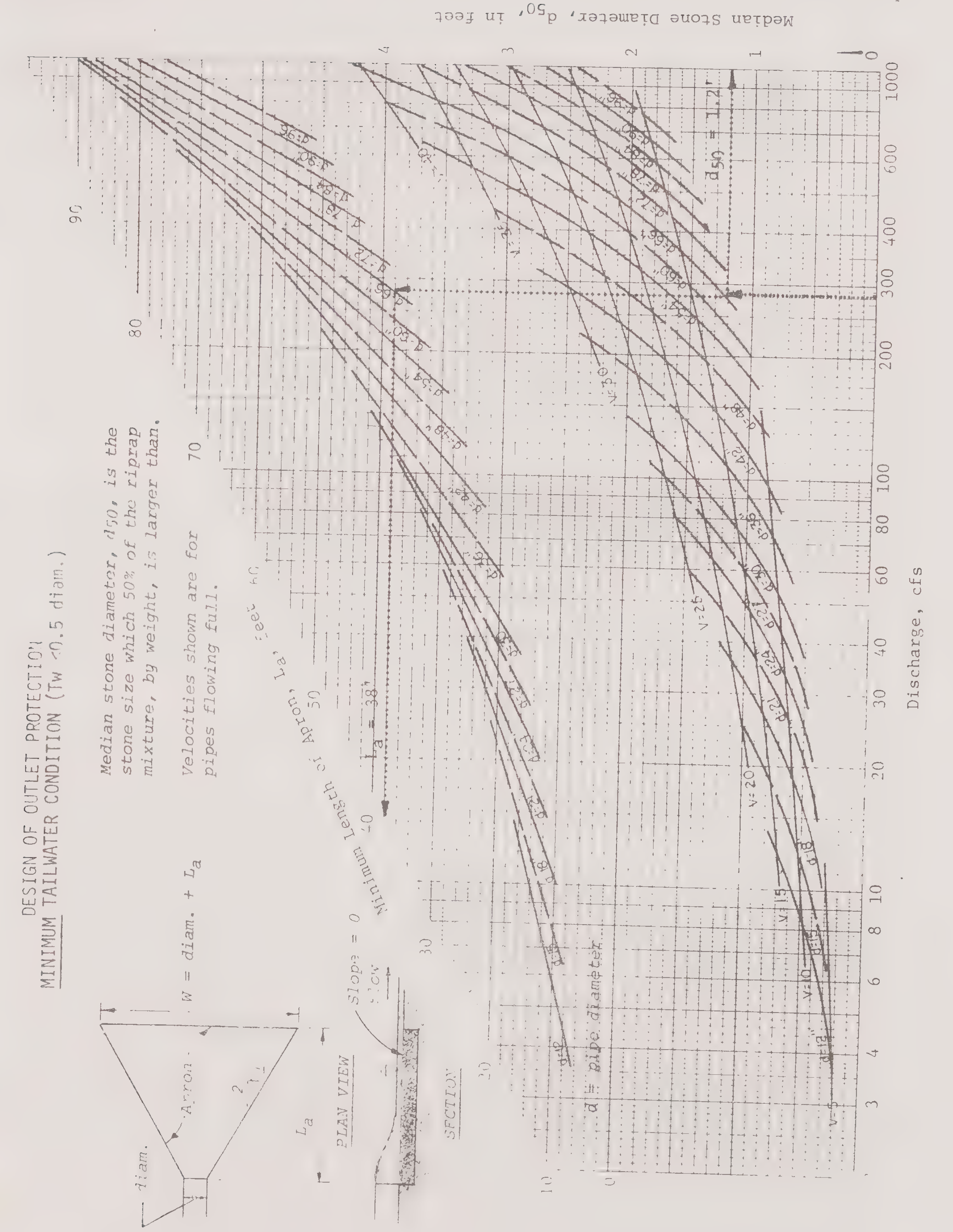
$$V = \frac{Q}{A} = \frac{600}{5.0 \times 10} = 12 \text{ fps}$$

At the intersection of the curve d=60" and V=12 fps, read d_{50} = 0.4'.

Then reading up to the d = 60" curve, read apron length = 40'.
Apron width, W = conduit width + 0.04 L_a = 10+(0.4)(40) = 26',
Largest stone size = 0.4 x 1.5 = 0.6' or 7"

This sample design procedure is provided by the USDA, Soil Conservation Service.


DESIGN OF OUTLET PROTECTION
MAXIMUM TAILWATER CONDITION (Tw ≥ 0.5 diam.)
Median stone diameter, d_{50}, is the stone size which 50% of the riprap mixture, by weight, is larger than.
W = diam. + 0.4 L_a
Velocities shown are for pipes flowing full.
Apron
5
1
L_a
diam.
PLAN VIEW
Tailwater ≥ 0.5 diam.
Flow
Slope = 0
diam.
SECTION
Median Stone Diameter, d_{50}, in feet
Minimum Length of Apron, L_a, feet
Discharge, cfs
d = pipe diameter


DESIGN OF OUTLET PROTECTION
MINIMUM TAILWATER CONDITION (Tw <0.5 diam.)
Median stone diameter, d_{50}, is the stone size which 50% of the riprap mixture, by weight, is larger than.
Velocities shown are for pipes flowing full.
W = diam. + L_a
diam.
Apron
L_a
PLAN VIEW
Slope = 0
SECTION
Minimum Length of Apron, L_a, feet
L_a = 38'
d_{50} = 1.2'
d = pipe diameter
Discharge, cfs
Median Stone Diameter, d_{50}, in feet

APPENDIX D

Sample Determinations of Subsurface Drain Sizes

Subsurface drains ordinarily are not designed to flow under pressure and the hydraulic gradient is considered to be parallel with the grade line. The flow in the subsurface drain is considered to be open-channel flow. The size of subsurface drain required for a given capacity is dependent on the hydraulic gradient and the roughness coefficient -- "n" value -- of the subsurface drain.

The "n" values for the different materials is as follows:

Description of Pipe or Tubing	"n" value
Plastic, smooth	0.011
Asbestos Cement	0.013
Bituminized Fiber	0.013
Concrete	0.015
Corrugated Plastic	0.015
Corrugated Metal	0.025

The Standard and Specifications for Subsurface Drain states that for a systematic pattern of drains, a drainage coefficient of 1 inch to be removed in 24 hours shall be used. This coefficient is equal to 0.042 cfs. per acre of area to be drained.

Where subsurface drainage is to be by a random system, a minimum inflow rate of 1.5 cfs. per 1,000 feet of line shall be used to determine the required capacity.

If surface water is allowed to enter the system, additional capacity must be provided for and the minimum design velocity shall be 2 feet per second.

The charts are set up for different "n" values. The abscissa of the chart is the hydraulic gradient in feet per foot and the ordinate is the capacity in cubic feet per second. On the chart are plotted the full flow capacity for different pipe diameters and a velocity line for 2 feet per second. The charts are used by going to the next higher pipe diameter line from the point of intersection of the hydraulic gradient and the capacity for the required pipe size since the design is for open-channel flow. Any point to the right or below the 2 feet per second line will have a velocity of less than 2 feet per second.

Examples using the charts are as follows:

This sample design procedure is provided by the USDA, Soil Conservation Service.

Example 1

A random subsurface drain is to be installed. This drain will be 700 feet in length and will be installed at a grade of 0.20%. Bituminized fiber pipe will be used. Determine the size and capacity of the drain.

Solution

From the standard, capacity required = 1.5 cfs per 1000 feet of length.

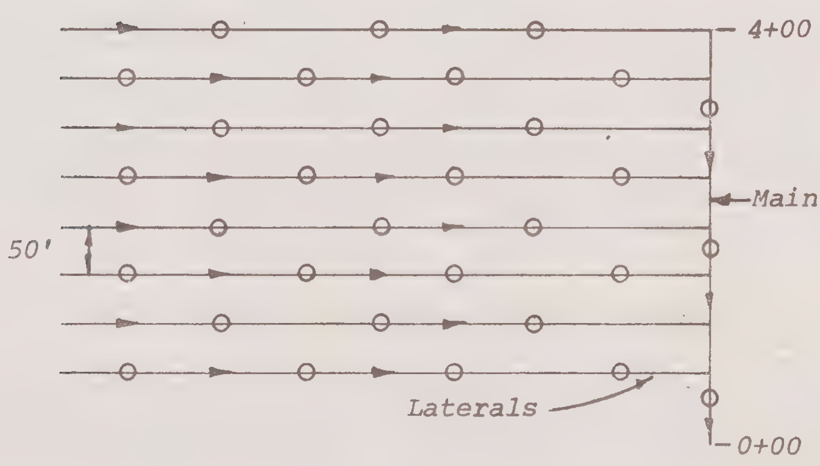
$$\text{Capacity} = \frac{700'}{1000'} \times 1.5 \text{ cfs per } 1000' = 1.05 \text{ cfs}$$

Using Subsurface Drain Capacity Chart for n = 0.013, capacity required = 1.05 cfs, and a gradient of 0.002 ft./ft., the size required is 12" and the actual capacity will be 1.58 cfs.

Example 2

A systematic pattern of subsurface drains is to be installed. There will be eight (8) laterals installed that will be spaced at fifty (50) feet center-to-center and each lateral will be 600 feet in length. The grade of the laterals will be 0.10%. The main will pick up these laterals and will be 400 feet in length. The grade of the main will be 0.10%. Determine the size and capacity of the laterals and the main at the outlet if corrugated plastic tubing is used.

PLAN VIEW



Solution

a. Size and capacity of laterals.

Each lateral will drain for a distance of 25 feet on each side of the line since the spacing is at 50 feet center-to-center. Therefore, each lateral will drain

$$\frac{600' \text{ (length) x } 50' \text{ (width)}}{43,560} = 0.69 \text{ acre}$$

Capacity required = 0.69 acre x 0.042 cfs per acre = 0.029 cfs. Using Subsurface Drain Capacity Chart for n = 0.015, capacity required = 0.029 cfs, and a gradient of 0.001 ft./ft., the size required is 4" and the actual capacity will be 0.052 cfs. (Note: Minimum size allowed is 4".)

b. Size and capacity of the main at the outlet.

For the first 25 feet of the main from the outlet, the main will drain for a distance of 25 feet on each side. For the remaining 375 feet, the main will drain only 25 feet on the one side since the other side is included in the drainage area for the laterals. The main will also drain the laterals. Therefore:

Drainage area from laterals:

= 8 x 0.69 acre = 5.52 acres

Drainage area from main:

$$= \frac{25' \text{ (length) x } 50' \text{ (width)}}{43,560} + \frac{375' \text{ (length) x } 25' \text{ (width)}}{43,560} = 0.24 \text{ acre}$$

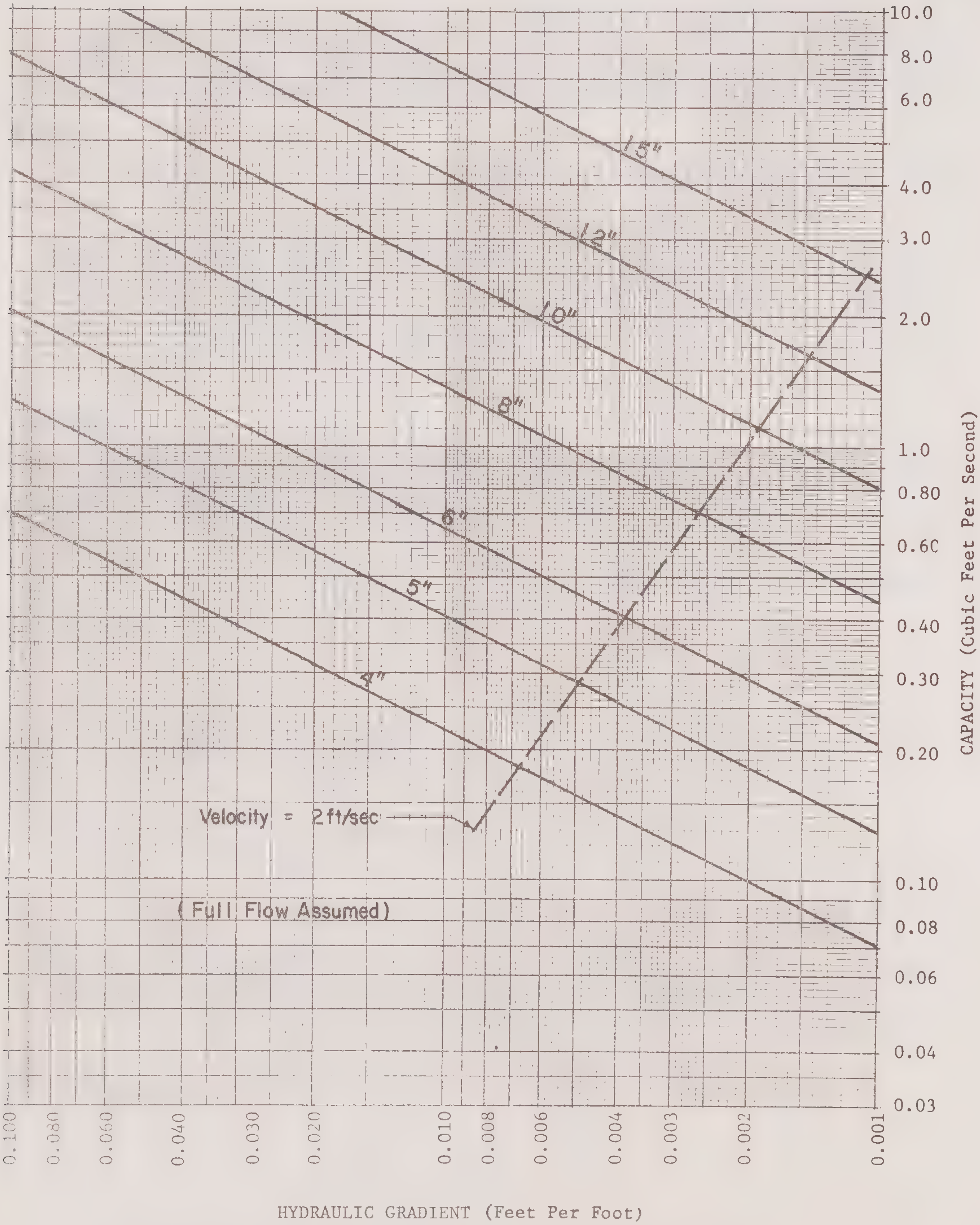
Total = 5.76 acres

Capacity required:

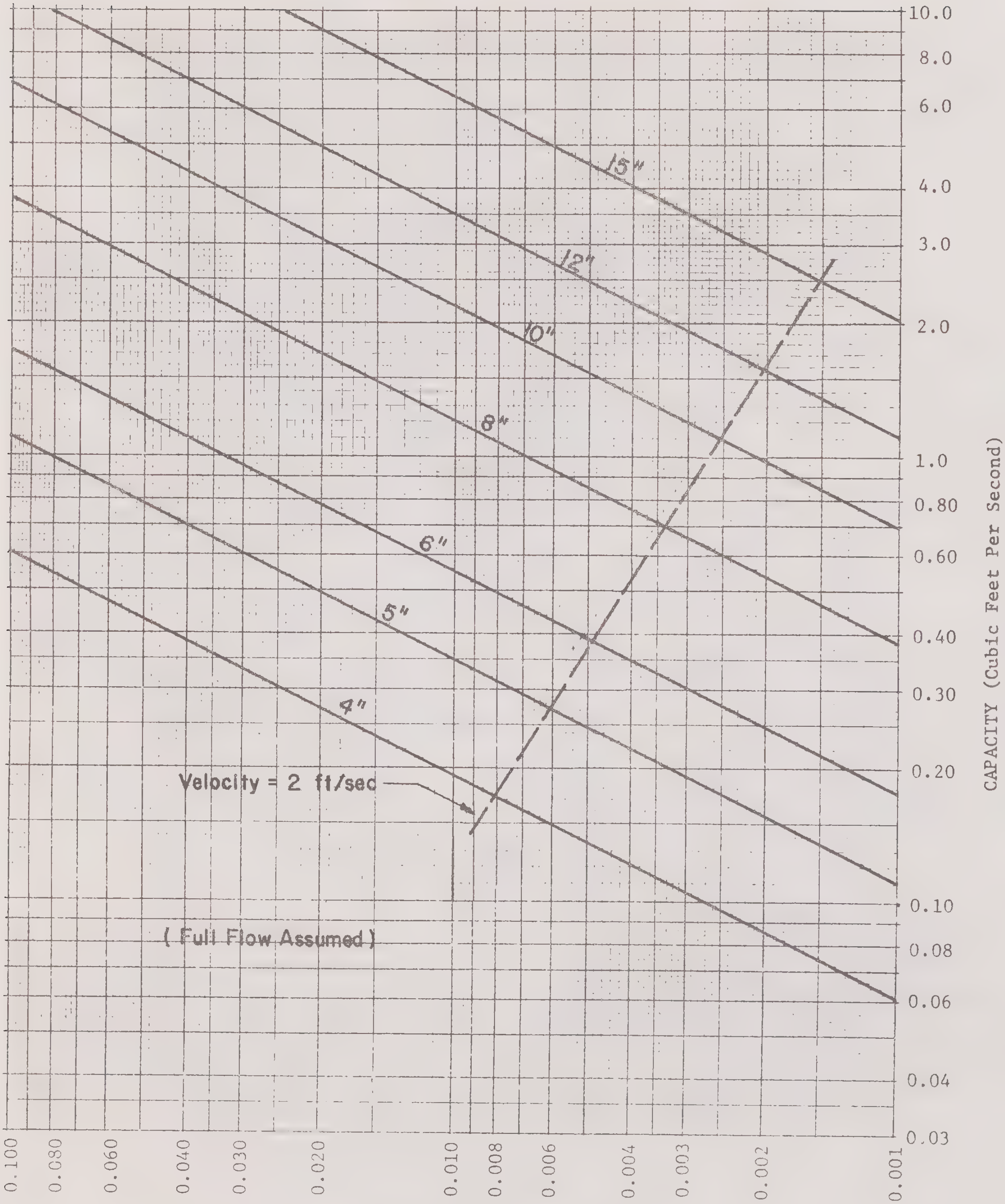
= 5.76 acres x 0.042 cfs/acre = 0.24 cfs.

Using Subsurface Drain Capacity Chart for n = 0.015, capacity required = 0.24 cfs, and a gradient of 0.001 ft./ft., the size required at the outlet is 8" and the actual capacity will be 0.33 cfs.

SUBSURFACE DRAIN CAPACITY CHART - n = 0.011 (14)

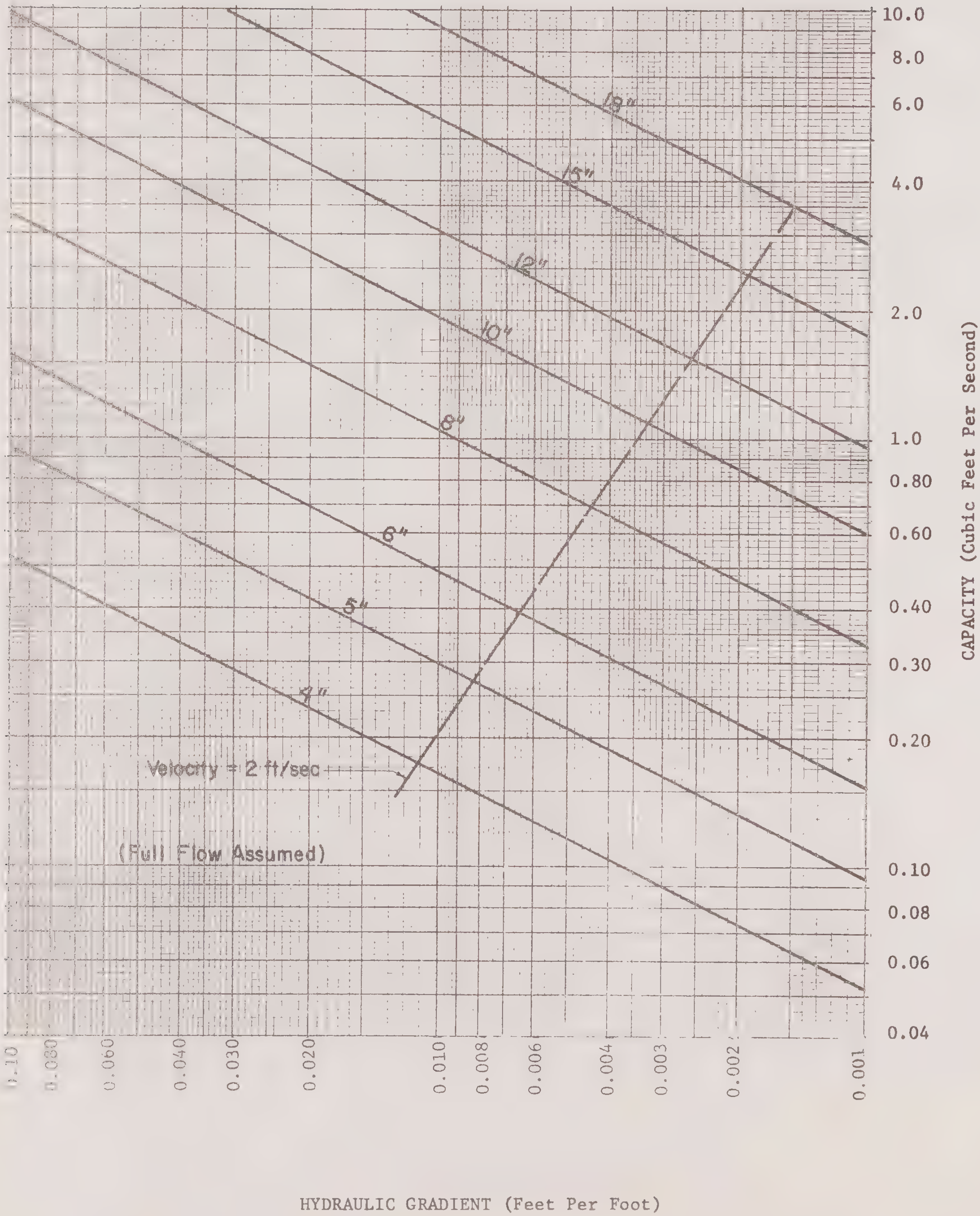


SUBSURFACE DRAIN CAPACITY CHART - n = 0.013

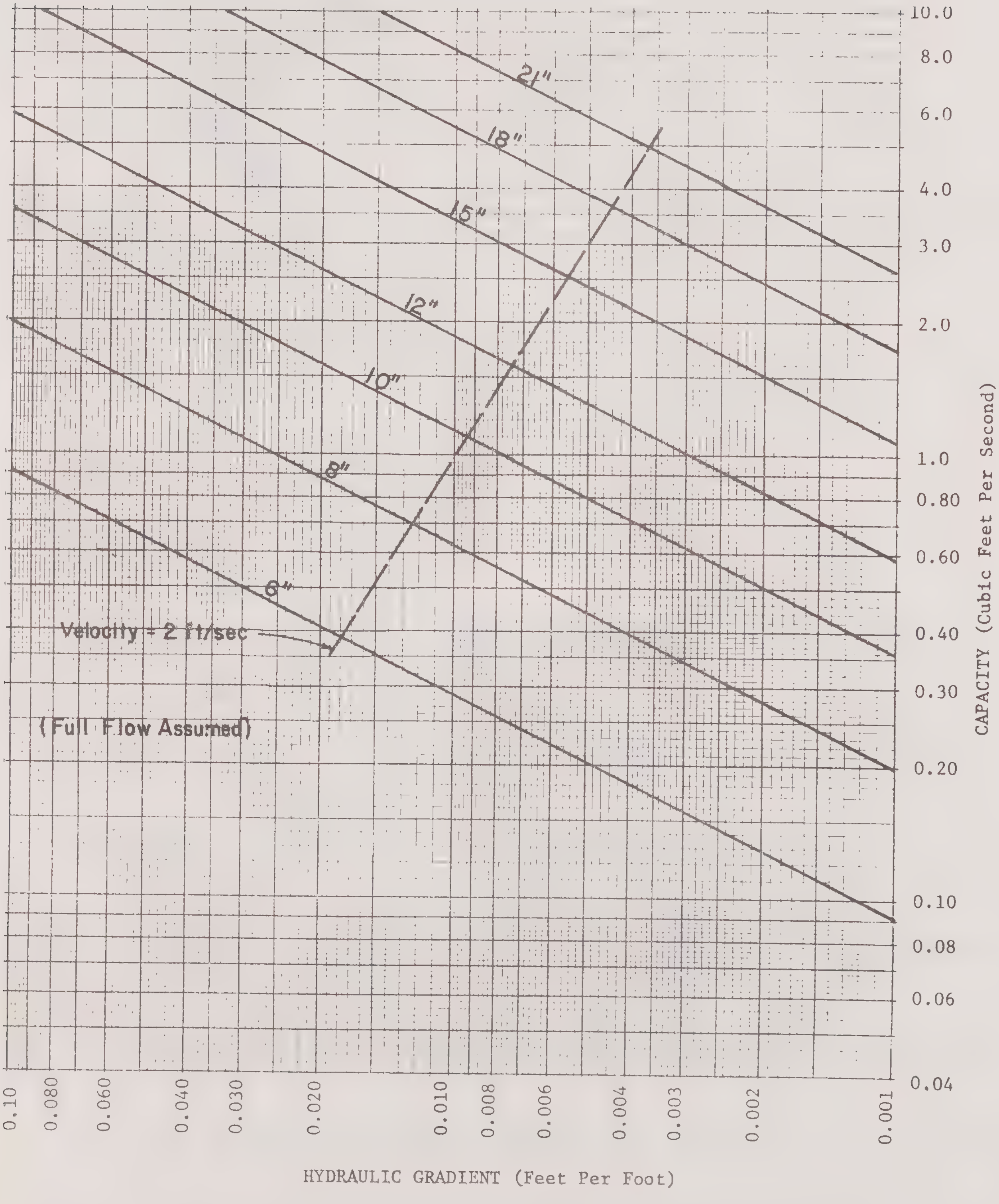


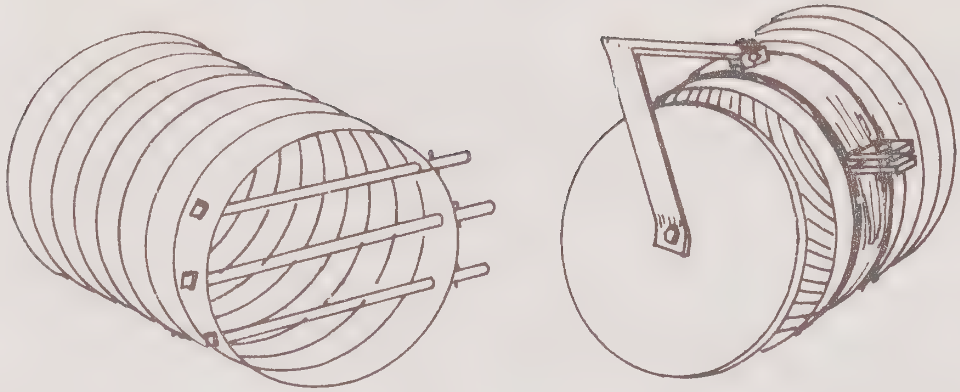
HYDRAULIC GRADIENT (Feet Per Foot)

SUBSURFACE DRAIN CAPACITY CHART - n = 0.015

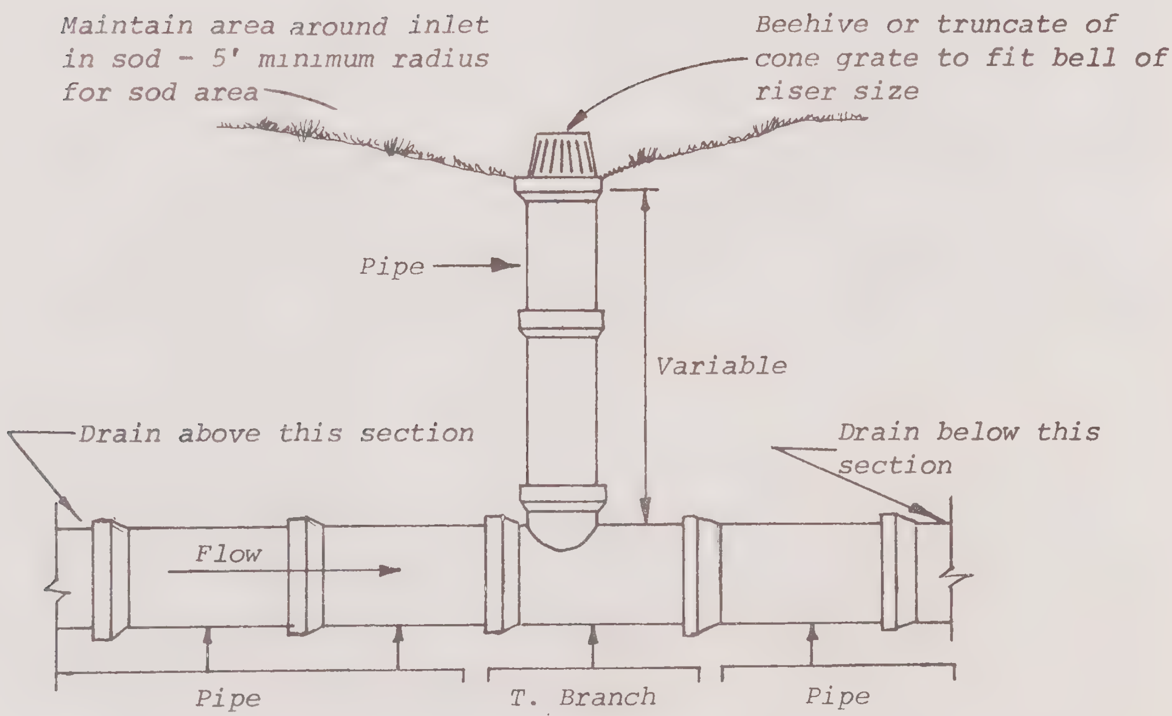


SUBSURFACE DRAIN CAPACITY CHART - n = 0.025





RODENT PROTECTION FOR OUTLET PIPE



SURFACE WATER INLET TO SUBSURFACE DRAIN

APPENDIX E

Design Method for the Selection of a Street Sweeping Schedule

The following listing gives the computer program which constitutes the Street Solids Washoff Model.

```
   // JOB ,DLVR),'ABAG,RUSSELL.202.40',CLASS=Y
   // EXEC FORTGCLG,REGION=150K
   //FORT.SYSIN DD *
  C      TITLE,STREEP
  C
  C  GIVEN RAIN SCHEDULE, SWEEPING EFFICIENCY, AND SOLIDS ACCUMULATION
  C  RATES, THIS PROGRAM CALCULATES:  SOLIDS SWEPT, SOLIDS WASHED OFF,
  C  NUMBER OF PASSES FOR EACH SEASON, AND THE UNIT COSTS.
  C
  C  REQUIRED INPUTS:
  C       LINE 1, SPACES 1 & 2
  C     LM:  NUMBER OF LOCATIONS (UP TO 4)
  C     LUM:  NUMBER OF LAND USES PER LOCATION (UP TO 3)
  C
  C       NEXT L LINES, LEFT JUSTIFY ON EACH LINE
  C     LOC(L):  NAME OF EACH LOCATION
  C
  C       NEXT LU LINES, LEFT JUSTIFY ON EACH LINE
  C     USE(LU):  NAME OF EACH LAND USE
  C
        INTEGER KS, LUM, LM
  C
  C       NEXT L LINES, LU F6.1 ENTRIES ABUTTING EACH OTHER
  C     SL(L,LU):  AVERAGE STREET SOLIDS LOAD FOR EACH LOCATION
  C         AND LAND USE.
  C
  C       NEXT L LINES, LU F8.4 ENTRIES ABUTTING EACH OTHER
  C     SLS(L,LU):  SLOPE OF THE SOLIDS LOADING RATE CURVE  -
  C         DAY'S LOAD INC. = LOAD X SLOPE + MAX. LOADING RATE
  C
  C       NEXT L LINES, LU F7.2 ENTRIES ABUTTING EACH OTHER
  C     SLM(L,LU):  MAXIMUM STREET SOLIDS LOADING RATE IN LBS PER
  C         CURB MILE PER DAY FOR EACH LOCATION AND LAND USE.
  C
  C       NEXT L LINES, LU F5.3 ENTRIES ABUTTING EACH OTHER
  C     SE(L,LU):  STREET SWEEPING EFFICIENCY FOR EACH LOCATION
  C         AND LAND USE.
  C
  C       NEXT LINE, L F6.2 ENTRIES ABUTTING EACH OTHER
  C     SC(L):  SWEEPING COSTS FOR EACH LOCATION IN DOLLARS PER
  C         CURB MILE PER PASS.
  C
        REAL R(1460), RA(4), RT, SE(4,3), SR(2), CR(2), SL(4,3),
       +RR12(730), RR34(730), SLS(4,3)
  C
  C       NEXT L LINES, LU F6.1 ENTRIES ABUTTING EACH OTHER
  C     CM(L,LU):  CURB-MILES FOR EACH LOCATION AND LAND USE.
  C
  C       NEXT LINE, LEFT JUSTIFY F4.3
  C     RT:  THRESHOLD RAINFALL IN INCHES PER DAY.
  C
  C       NEXT LINE, L F5.3 ENTRIES ABUTTING EACH OTHER
  C     RA(L):  RAINFALL ADJUSTMENT FACTOR.
```

```
C
C   VARIABLES AND ARRAYS:
       REAL WD(2,10,3), LOC(4,5), USE (3,3), NP(2,10), NR(2),
      +UC(2), AR(2), SC(4), SEA(2,5), SEC(2), USR(2),
      +SLM(4,3), D, WDF(2), UWF(2,10,3), CM(4,3), WFT(2), SCT(2)
       REAL NPS(2), SPR, SPRS, R1(2,3), R2(2,3), R4(2,3), R6(2,3),
      +SPY1, SS2, SPY2, SP12, SS1, B1, B2, A, RSLD(2,3), RINT(2,3),
      +RIEE(2,3)
C
C   FIRST TWO YEARS OF RAINFALL RECORD:  10/1/69 THROUGH 9/30/71.
C
       DATA RR12/9*.0,.03,3*.0,.03,.36,.19,.01,18*.0,.79,.13,.01,
      +26*.0,.01,3*.0,.27,.0,.08,.01,6*.0,.06,.28,.03,.51,2*.0,.01,
      +.31,14*.0,.66,.04,.65,.02,.04,.95,.26,.2,.08,.0,.1,.31,.19,.0,
      +.19,.05,2*.0,.28,12*.0,.14,.01,.02,.13,.34,2*.0,.23,.05,9*.0,
      +.27,.31,1.05,2*.0,1.01,3*.0,.07,.04,.01,33*.0,.13,5*.0,.05,
      +6*.0,.03,13*.0,.02,27*.0,.1,134*.0,.05,.06,.0,.24,10*.0,.3,.36,
      +.14,.53,5*.0,.02,11*.0,.24,.6,.07,.04,2.72,1.13,.07,.46,.38,.0,
      +.1,3*.0,.01,6*.0,.23,.3,.22,.73,.06,.79,.25,3*.0,.02,.19,.11,
      +.0,.04,2*.0,.1,.01,8*.0,.09,.46,.13,.1,4*.0,.01,.01,26*.0,.24,
      +.0,.13,.03,7*.0,.14,12*.0,.58,.02,.25,8*.0,.14,.0,.25,.32,5*.0,
      +8*.0,.12,.03,2*.0,.38,2*.0,.16,.34,.0,.02,12*.0,.03,10*.0,.01,
      +13*.0,.02,.01,.01,86*.0,.01,36*.0,.12/
C
C   SECOND TWO YEARS OF RAINFALL RECOND:, 10/1/71 THROUGH 9/30/73.
C
       DATA RR34/41*.0,.06,.12,.26,
      +13*.0,.01,.17,.08,2*.0,.68,.09,2*.0,.02,2*.0,.02,.11,.0,.03,.0,
      +.01,7*.0,.56,.28,.11,.69,.0,.6,.0,.09,20*.0,.01,3*.0,.08,.0,
      +.22,.03,.86,.01,5*.0,.02,.05,.22,16*.0,.03,5*.0,.01,21*.0,.07,
      +13*.0,.09,.05,4*.0,.09,.0,.11,10*.0,.17,45*.0,.14,108*.0,.01,
      +.59,4*.0,.01,.0,.02,4*.0,.33,.34,.08,.15,.04,.44,.26,.4,.1,.02,
      +15*.0,.02,.72,2*.0,.17,2*.0,.58,1.23,.0,.65,1.23,.39,.44,.0,
      +.02,.03,13*.0,.03,.09,.0,.31,.26,.01,7*.0,.04,.24,.03,.07,2*.0,
      +.02,.0,.03,3*.0,.05,10*.0,.4,.97,.07,.16,4*.0,1.38,.22,.8,.02,
      +.0,.12,3*.0,.3,3*.0,.07,.57,.04,2*.0,.31,.69,.0,1.08,.15,.0,
      +.04,.37,.78,.16,.5,.25,9*.0,.21,.0,.53,.65,.25,2*.0,.44,.13,.0,
      +.34,.0,.27,2*.0,.21,7*.0,.25,.66,.35,4*.0,.02,3*.0,.06,
      +.02,12*.0,.04,.01,39*.0,.01,121*.0,.01,.03,6*.0/
       DO 5 I=1,730
       R(I)=RR12(I)
       R(I+730)=RR34(I)
     5 CONTINUE
       DATA SEA/'SEPT','APRI','EMBE','L TH',
      +'R TH','RU A','RU M','UGUS','ARCH','T   '/
       IDIN=5
       IDOUT=6
C
C   READ THE JOB INPUTS.
C
       READ (IDIN,10) LM, LUM
    10 FORMAT (2I1)
       READ (IDIN,15) ((LOC(J,K), K=1,5), J=1,LM)
    15 FORMAT (5A4)
       READ (IDIN,20) ((USE(J,K),  K=1,3), J=1,LUM)
    20 FORMAT (3A4)
```

```
      READ (IDIN,25) ((SL(J,K), K=1,LUM), J=1,LM)
   25 FORMAT (3F6.1)
      READ (IDIN,27) ((SLS(J,K), K=1,LUM), J=1,LM)
   27 FORMAT (3F8.4)
      READ (IDIN,30) ((SLM(J,K), K=1,LUM), J=1,LM)
   30 FORMAT (3F7.2)
      READ (IDIN,35) ((SE(J,K), K=1,LUM), J=1,LM)
   35 FORMAT (3F5.3)
      READ (IDIN,40) (SC(J), J=1,LM)
   40 FORMAT (4F6.2)
      READ (IDIN,25) ((CM(J,K), K=1,LUM), J=1,LM)
      READ (IDIN,45) RT
   45 FORMAT (F4.3)
      READ (IDIN,46) (RA(J), J=1,LM)
   46 FORMAT (4F5.3)
C
C  EXAMINE EACH LOCATION.
C
      DO 300 L=1,3
      WRITE (IDOUT,105)
  105 FORMAT ('1ABAG - STREET SWEEPING EFFECTIVENESS MODEL',
     +/,'        BY PETER RUSSELL, MARCH 1980',//)
      WRITE (IDOUT,110) (LOC(L,K), K=1,5)
  110 FORMAT ('0', 10X, 5A4, //)
C
C  PRINT OUT THE PARAMETERS USED FOR THE LOCATION.
C
      WRITE (IDOUT,112)
  112 FORMAT ('   LAND USE     AVE. LOAD    ACCUM. SLOPE', 4X,
     +'MAX. ACCUM RATE', 7X, 'SWEEPING', 8X, 'CURB-MILES', /, 16X,
     +'LB/C-MI', 24X, 'LB/C-MI/DAY', 8X, 'EFFICIENCY',//)
      DO 400 LU=1,LUM
  400 WRITE (IDOUT,114) ((USE(LU,K), K=1,3), SL(L,LU), SLS(L,LU),
     +SLM(L,LU), SE(L,LU), CM(L,LU))
  114 FORMAT ('0',3A4,4X,F5.0,12X,F7.4,9X,F6.2,13X,F4.3,12X,F6.1)
      WRITE (IDOUT,116) SC(L)
  116 FORMAT (//, '0STREET SWEEPING COST:  $', F5.2, '/C-MI/PASS.')
      WRITE (IDOUT,118) RA(L), (LOC(L,K), K=1,5), RT
  118 FORMAT('0RAINFALL ADJUSTMENT FACTOR  = ', F4.2, ' FOR ',
     +5A4, '.', //, ' THE THRESHOLD RAINFALL FOR COMPUTING',
     +' WASHOFF IS ', F3.2, ' INCHES/DAY.')
      DO 350 I=1,2
      DO 350 J=1,LUM
      R1(I,J)=0.
      R2(I,J)=0.
      R4(I,J)=0.
      R6(I,J)=0.
  350 CONTINUE
C
C  EXAMINE SWEEP PERIODS OF 1, 2, 4, 7, 11, 16, 22, 29 AND 37 DAYS.
C
      SP=1.
      DO 200 KA=1,10
      SP=SP+KA-2
      IF (KA.EQ.1) SPR=0.
      IF (KA.EQ.1) SPRS=0.
```

```
      DO 200 LU=1,LUM
      IF (KA.EQ.1) SP=9999.
C
C  SET THE BOOKKEEPING VARIABLES EQUAL TO ZERO.
C
      DO 500 KS=1,2
      NP(KS,KA)=0.
      IF (KA.EQ.1) NPS(KS)=0.
      SR(KS)=0.
      NR(KS)=0.
      WD(KS,KA,LU)=0.
      CR(KS)=0.
  500 CONTINUE
C
C  EXAMINE EACH LAND USE IN THE LOCATION.
C
      SS=SL(L,LU)
      WRITE (IDOUT,105)
      WRITE (IDOUT,110) (LOC (L,K), K=1,5)
      WRITE (IDOUT,120) SP
  120 FORMAT (' FOR A SWEEPING FREQUENCY OF ONCE EVERY ',
     + F5.0, ' DAYS:')
      WRITE (IDOUT,125) (USE(LU,K), K=1,3)
  125 FORMAT (' ', 3A4, 'LAND USE:', /)
C
C  RUN FOUR YEAR'S RAIN DATA SEVEN TIMES, EACH BEGINNING
C       WITH A DIFFERENT DAY OF THE WEEK.
C
      D=0.
      NY=7
      DO 100 ID=1,NY
C
C  RUN FOUR YEAR'S DATA.
C
      DO 100 I=1,1460
      D=D+1
C
C  ADD DAY'S INCREMENT OF SOLIDS TO THE STREET SURFACE.
C
      SS=SS+SLS(L,LU)+SLM(L,LU)
C
C  IDENTIFY THE SEASON:  1=NOVEMBER THRU MARCH, 2=APRIL THRU AUGUST.
C
      KS=2
      IF ((I.LE.182).OR.((I.GE.336).AND.(I.LE.547)).OR.((I.GE.701)
     +.AND.(I.LE.912)).OR.((I.GE.1066).AND.(I.LE.1277)).OR.
     +(I.GE.1431)) KS=1
C
C  IS THE DAY A MULTIPLE OF THE SWEEP PERIOD?
C
      M=0
      IF (D/SP-AINT(D/SP).NE.0.) M=1
C
C  IS THE DAY A SUNDAY OR SATURDAY?
C
      IF(((D-1)/7.-AINT((D-1)/7.).EQ.0.).OR.(D/7.-
     +AINT(D/7.).EQ.0.)) M=1
```

```
C
C   IS THE DAY A MONDAY FOLLOWING A WEEKEND MULTIPLE OF THE SWEEP
C         PERIOD?
C
      IF (((D-2)/7.-AINT((D-2)/7.).EQ.0.).AND.(((D-1)/SP-
     +AINT((D-1)/SP).EQ.0.).OR.((D-2)/SP-AINT((D-2)/
     +SP).EQ.0.))) M=0
C
C   IS THE DAY'S RAIN ABOVE THE THRESHOLD?
C
      IF (R(I)*RA(L).GE.RT) GO TO 50
C
C   IS SWEEPING TO BE DONE?
C
      IF (M.EQ.1) GO TO 100
      IF (SP.EQ.9999.) GO TO 100
C
C   SWEEP THE STREET, TALLY SOLIDS AND COUNT THE PASS.
C
      NP(KS,KA)=NP(KS,KA)+1
      SR(KS)=SR(KS)+SS*SE(L,LU)
      SS=SS*(1-SE(L,LU))
      GO TO 100
C
C   RAIN EVENT:  TALLY SOLIDS, COUNT THE RAIN DAY AND TALLY RAIN.
C
   50 NR(KS)=NR(KS)+1
      WD(KS,KA,LU)=WD(KS,KA,LU)+SS*(1-EXP(-3.91*R(I)*RA(L)))
      SS=SS*EXP(-3.91*R(I)*RA(L))
      CR(KS)=CR(KS)+(R(I)*RA(L))
  100 CONTINUE
      IF ((LU.EQ.1).AND.(KA.NE.1)) SPR=SPR+1/SP
      IF ((LU.EQ.1).AND.(KA.NE.1)) SPRS=SPRS+(1/SP)**2
      DO 200 KS=1,2
      NP(KS,KA)=NP(KS,KA)/(4*NY)
      IF (LU.EQ.1) NPS(KS)=NPS(KS)+NP(KS,KA)
      SR(KS)=SR(KS)/(4*NY)
      NR(KS)=NR(KS)/(4*NY)
      WD(KS,KA,LU)=WD(KS,KA,LU)/(4*NY)
      WDF(KS)=WD(KS,1,LU)-WD(KS,KA,LU)
      CR(KS)=CR(KS)/(4*NY)
      AR(KS)=CR(KS)/NR(KS)
      SEC(KS)=SC(L)*NP(KS,KA)
      IF (NP(KS,KA).EQ.0.) GO TO 900
      UC(KS)=SC(L)*NP(KS,KA)/SR(KS)
      USR(KS)=SR(KS)/NP(KS,KA)
      UWF(KS,KA,LU)=SC(L)*NP(KS,KA)/WDF(KS)
      GO TO 800
  900 USR(KS)=0.
      UC(KS)=0.
      UWF(KS,KA,LU)=0.
  800 CONTINUE
      WFT(KS)=WDF(KS)*CM(L,LU)
      SCT(KS)=SEC(KS)*CM(L,LU)
```

```
C
C  TABULATE THE RESULTS FOR EACH SEASON.
C
      WRITE (IDOUT,150) (SEA(KS,K), K=1,5)
  150 FORMAT ('1', 24X, 6A4)
      WRITE (IDOUT,152) NR(KS), CR(KS), AR(KS)
  152 FORMAT ('0', F5.1, ' SIGNIFICANT RAIN DAYS.', 12X,
     +'CUMULATIVE TOTAL  = ', F4.1, ' INCHES/SEASON.',
     +/, ' THE AVERAGE RAIN  = ', F4.2, ' INCHES/DAY.')
      WRITE (IDOUT,154) NF(KS,KA), SF(KS), USR(KS), SEC(KS), UC(KS),
     +WD(KS,KA,LU)
  154 FORMAT ('0ACTIVITY  =  ', F5.1, ' PASSES/SEASON.',
     +/, '0SOLIDS SWEPT UP   = ', F7.1, ' LB/C-MI  = ', F8.2,
     +' LB/C-MI PASS.', /, ' SWEEPING COST  =  $', F8.2,
     +'/C-MI/SEASON  =  $', F6.3, '/LB SWEPT UP.', /,
     +'0WASHOFF  = ', F7.1, ' LB/C-MI/SEASON.')
      WRITE (IDOUT,156) WOF(KS), UWF(KS,KA,LU)
  156 FORMAT ('0WASHOFF FORGONE  = ', F7.1, ' LB/C-MI/SEASON  =  $',
     +F8.3, '/LB PREVENTED FROM WASHING OFF.')
      WRITE (IDOUT,158) WFT(KS), SCT(KS)
  158 FORMAT ('  TOTAL WASHOFF FORGONE  = ', F10.0, ' LB/SEASON.',
     + '       TOTAL COST  =  $', F10.0, '/SEASON.', //)
      IF (KA.EQ.1) SP=1
      IF (KA.EQ.1) GO TO 200
      R1(KS,LU)=R1(KS,LU)+1
      R2(KS,LU)=R2(KS,LU)+UWF(KS,KA,LU)/SP
      R4(KS,LU)=R4(KS,LU)+UWF(KS,KA,LU)
      R6(KS,LU)=R6(KS,LU)+(UWF(KS,KA,LU))**2
  200 CONTINUE
      WRITE(IDOUT,105)
      WRITE (IDOUT,110) (LOC(L,K), K=1,5)
      WRITE(IDOUT,162)
  162 FORMAT('  THE BEST FIT COEFFICIENTS DEFINING THE',
     +' UNIT COST OF SOLIDS KEPT FROM WASHING OFF ARE:', /,
     +15X, '$/LB  =  A X (1/SWEEP PERIOD) + B')
      DO 300 KS=1,2
      WRITE (IDOUT, 163)
  163 FORMAT (/)
      WRITE (IDOUT,150) (SEA(KS,K), K=1,5)
      DO 310 LU=1,LUM
      RSLO(KS,LU)=(R1(KS,LU)*R2(KS,LU)-SPR*R4(KS,LU))/
     +(R1(KS,LU)*SPRS-SPR**2)
      RINT(KS,LU)=(R4(KS,LU)*SPRS-SPR*R2(KS,LU))/
     +(R1(KS,LU)*SPRS-SPR**2)
      RSEE(KS,LU)=SQRT((R6(KS,LU)-RINT(KS,LU)*R4(KS,LU)-
     +RSLO(KS,LU)*R2(KS,LU))/(R1(KS,LU)-2))
      WRITE (IDOUT,164) (USE(LU,K), K=1,3), RSLO(KS,LU), RINT(KS,LU),
     +RSEE(KS,LU)
  164 FORMAT ('0', 3A4, 10X, 'A  = ', F9.5, 10X, 'B  = ', F9.5, /,
     +' STANDARD ERROR OF ESTIMATE  =  $', F7.3, '/LB.')
  310 CONTINUE
      SPY1=0.
      SS2=0.
      SPY2=0.
      SP12=0.
      SS1=0.
      SP=1.
```

```
      DO 330 KA=2,10
      SP=SP+KA-2
      SPY1=SPY1+(NP(KS,KA)-SPP/P1(KS,1))*(1/SP-SPP/P1(KS,1))
      SS2=SS2+((1/SP)**2-SPPS/P1(KS,1))**2
      SPY2=SPY2+(NP(KS,KA)-SPP/P1(KS,1))*((1/SP)**2-SPPS/P1(KS,1))
      SP12=SP12+(1/SP-SPP/P1(KS,1))*((1/SP)**2-SPPS/P1(KS,1))
      SS1=SS1+(1/SP-SPP/P1(KS,1))**2
  330 CONTINUE
      B1=(SPY1*SS2-SPY2*SP12)/(SS1*SS2-(SP12)**2)
      B2=(SPY2*SS1-SPY1*SP12)/(SS1*SS2-(SP12)**2)
      A=NPS(KS)/P1(KS,1)-B1*SPP/P1(KS,1)-B2*SPPS/P1(KS,1)
      WRITE (IDOUT,170) (SEA(KS,K), K=1,5), A, B1, B2
  170 FORMAT ('0NUMBER OF PASSES DURING ', 5A4, ' = ', F7.3, ' + ',
     +F8.3, ' X (1/SWEEP PERIOD) + ', F8.3, ' X (1/SWEEP PERIOD)**2.'
     +, //)
  300 CONTINUE
      STOP
      END
/*
//GO.SYSIN DD *
33
CITY OF SAN JOSE
CITY OF SAN JOSE
CITY OF SAN JOSE
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
 489.1 757.6 626.7
 489.1 757.6 626.7
 489.1 757.6 626.7
   .9722   .9859   .9961
   .9722   .9859   .9961
   .9722   .9859   .9961
  30.56  24.47  15.32
  30.56  24.47  15.32
  30.56  24.47  15.32
 .365 .323 .36
 .3   .3   .3
 .2   .2   .2
 14.00 14.00 14.00
1770.  324.2 130.4
1770.  324.2 130.4
1770.  324.2 130.4
.2
1.   1.   1.
/*
//
```

TABLE E-1

CITY OF SAN JOSE
(REPORTED SWEEPER EFFICIENCIES)

Alternative	Season						Total Washoff Prevented (1000s lb/yr)	Total Cost (1000s $/year)	Unit Cost ($/lb)
	Sept. - Mar.			Apr. - Aug.					
	Res.	Com.	Ind.	Res.	Com.	Ind.			
1			M				168	12	.07
2			B				276	25	.09
3		M	B				544	54	.10
4		B	B				759	87	.11
5		B	W				834	111	.13
6	M	B	W				1860	271	.15
7	B	B	W				2750	448	.16
8	B	W	W				2950	509	.17
9	W	W	W				3990	842	.21
10	W	W	D				4090	1040	.25
11	W	D	D				4490	1530	.34
12	D	D	D				6750	4210	.62
13	D	D	D	M			6770	4340	.64
14	D	D	D	B			6800	4480	.66
15	D	D	D	B	M		6800	4510	.66
16	D	D	D	W	M		6830	4770	.67
17	D	D	D	W	B		6830	4800	.70
18	D	D	D	W	W		6840	4850	.71
19	D	D	D	W	W	M	6840	4860	.71
20	D	D	D	W	W	B	6840	4870	.71
21	D	D	D	W	W	W	6840	4890	.71
22	D	D	D	D	W	W	6930	7050	1.02
23	D	D	D	D	D	W	6940	7440	1.07
24	D	D	D	D	D	D	6950	7600	1.09

W = weekly
D = daily
M = monthly

The listing shows a run using San Jose data. Lines 62 through 92 of the listing provide the four years rainfall record. Lines 353 through 377 are the model inputs which are discussed in the Design Considerations section of the standard. The illustrated San Jose run examines existing street cleaning efficiency (line 369) as well as hypothetical efficiencies of 20% and 30% (lines 370 and 371). The program output consists of one page of results for each land use of each location for each of the cleaning frequencies: never, daily, once every other day, once every fourth day, weekly, once every 11th, 16th, 22nd, 29th and 37th day. Each page of output gives for the September through March season and for the April through August season the unit cost associated with that location, land use and cleaning frequency in dollars per pound of solids prevented from washing off. To allow computation of results for sweep frequencies other than those listed above, the last page of output for each location gives the coefficients of the equation defining the unit cost of preventing solids from washing off as a function of the cleaning frequency.

The most cost effective street cleaning schedule for a location is constructed by starting with the season and land use having the lowest unit cost of preventing solids from washing off, and successively adding to the program less cost effective seasons and land uses until the available budget is exhausted. Russell (1980) gives a more detailed explanation of the use of the Street Solids Washoff Model.

Figures E1 and E2 illustrate the results obtained from application of the model. The San Jose example is an instance where rainy season street cleaning is much more cost effective than cleaning in the dry season. Cleaning effectiveness is approximately the same for the three land uses.

Table E1 provides a sample direct comparison of sweeping schedules, generated by the model, which can be used to select a program tailored to fit water quality needs and budgetary constraints.

Figure E3 gives the flow diagram for the Street Solids Washoff Model.

Reference

Russell, Peter. 1980. "Regional Evaluation of Street Sweeping as a Water Quality Control Measure." ABAG Water Quality Technical Memorandum No. 38.

Unit cost of preventing solids from washing off versus sweep frequency

City of San Jose

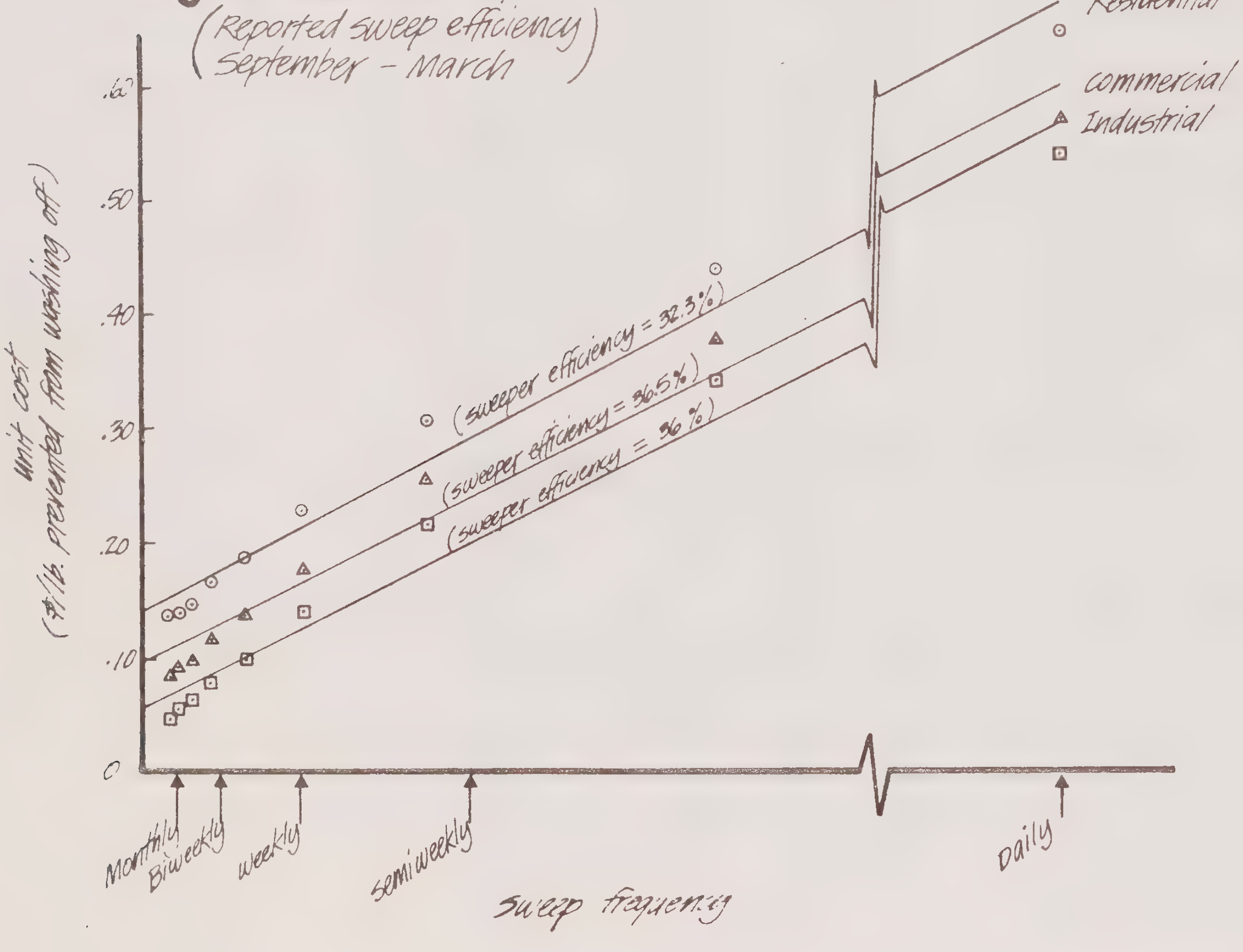


Figure E1

Unit cost of preventing solids from washing off versus sweep frequency

City of San Jose (Reported sweep efficiency, April - August)

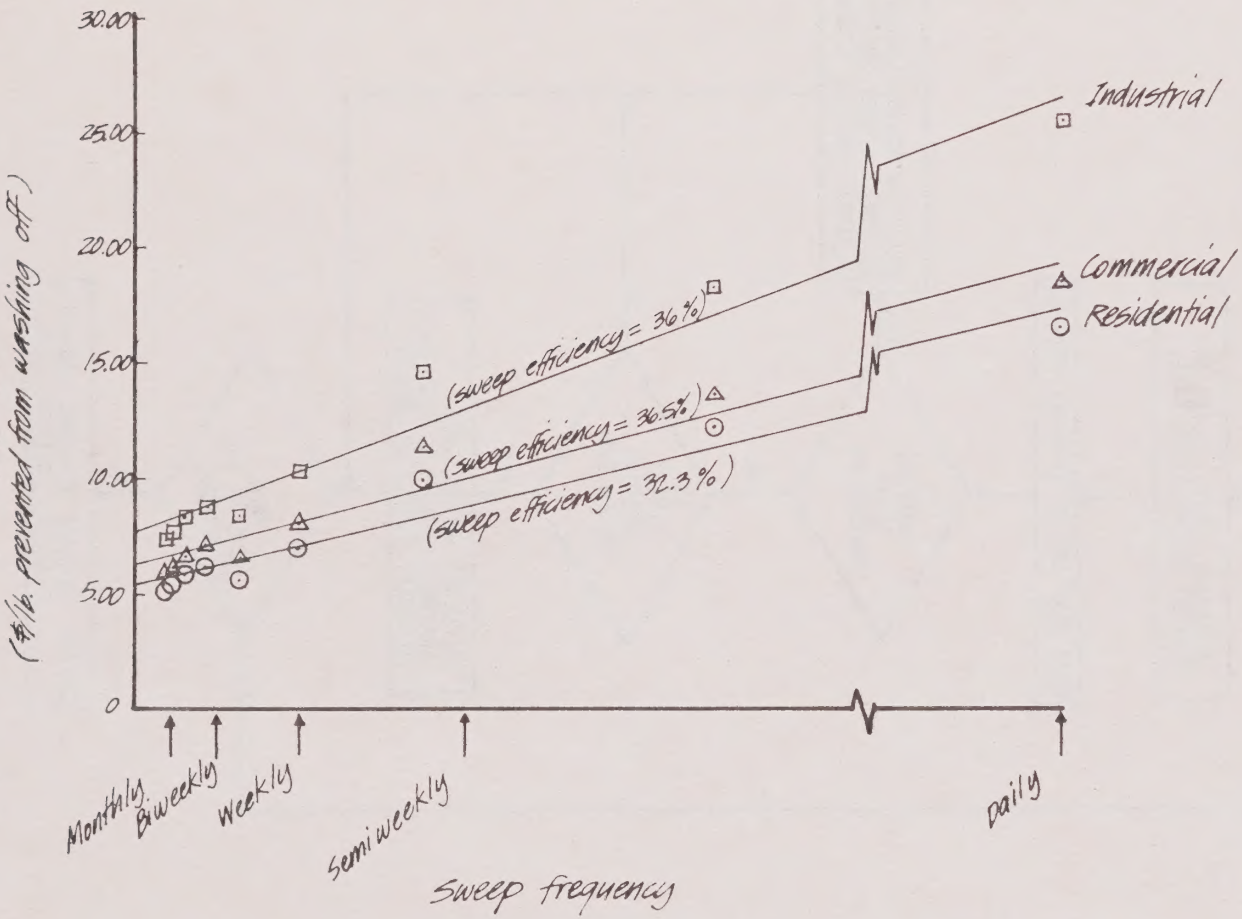
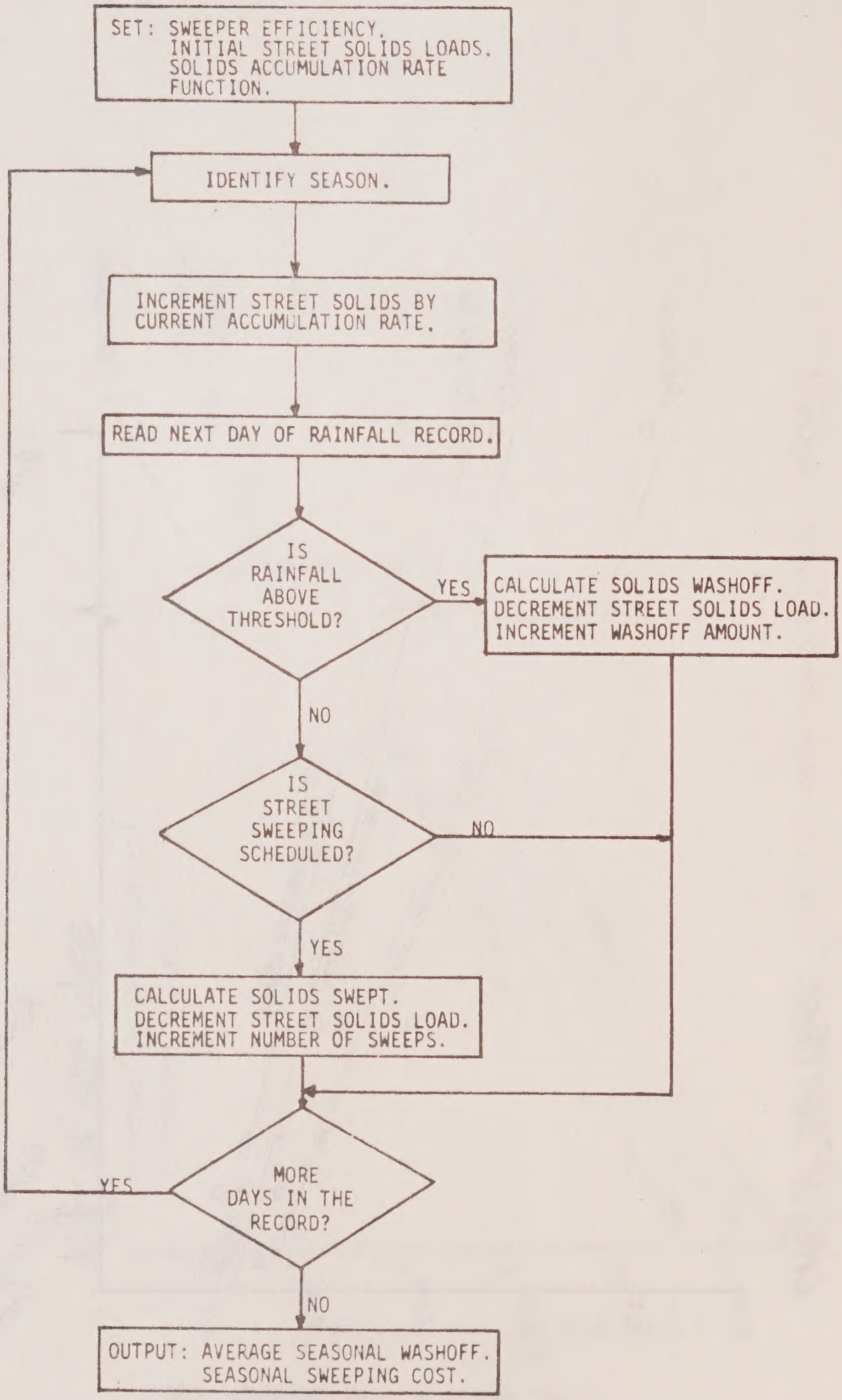


Figure E2

Figure E3



SOLIDS WASHOFF FLOW DIAGRAM